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of the universe? PAGE 44

Star clusters' ancient
secrets revealed PAGE 48

How to observe the
Pinwheel Galaxy PAGE 72

November 2003

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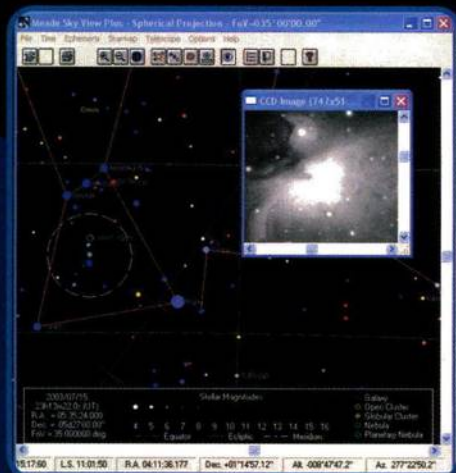
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*For use with other Meade telescopes see the Meade web site.



Planetarium program showing Orion region.



Image of Mars made with an LPI connected to a 12" LX200GPS, a composite of 36 images automatically selected and registered by the Autostar Suite software. Control of the telescope was via Autostar Suite remotely over a network connection.



Moon image taken with altazimuth mounted 8" LX90 by first-time user of the LPI imager and software.



Meade LPI imager mounted on LX200GPS telescope.

***Visit the Meade web site at www.meade.com for complete description of features and detailed specifications.**



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5" Model AR-5EC Achromatic Refractor	579

#497 Autostar Controller,
for EC-models 149

Meade Model SN-8
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Telescope with standard-equipment
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(below, left to right) 8" Model SC-8 Schmidt-Cassegrain; 5" Model AR-5 and 6" Model AR-6 Achromatic Refractors.

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SN-10	- \$150, SC-8 - \$175

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AR-6 - \$95

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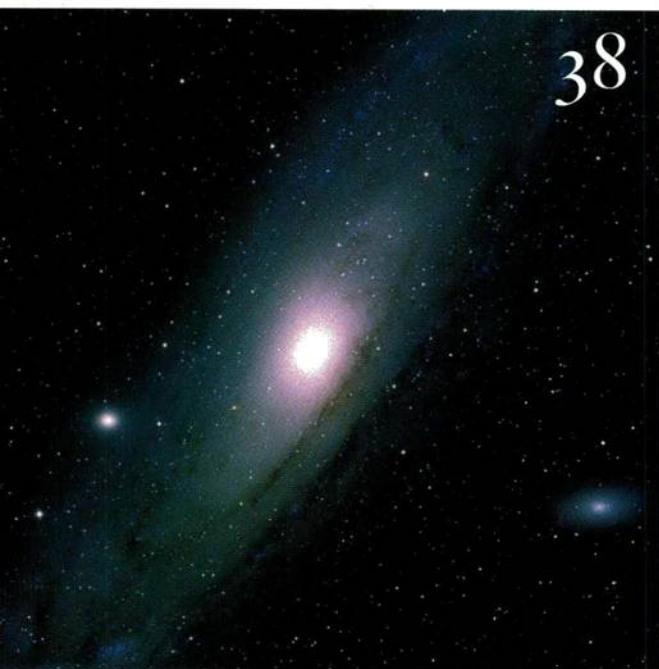
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38 Order out of chaos

Like a flotilla of PT boats accompanying two giant aircraft carriers, dozens of dwarf galaxies surround and interact with the Milky Way and Andromeda galaxies. Now, astronomers are finding our Local Group forms a microcosm of the universe at large. RAY VILLARD

COSMOLOGY

44 Absurd universe

All that we see is not all there is. In fact, what's visible to us makes up only 0.5% of the total mass of the universe. Is that absurd? Find out in this intriguing story about dark matter and dark energy. MICHAEL S. TURNER

GALACTIC ASTRONOMY

48 Great balls of fire

Considered retirement homes for old stars, globular clusters have long been overlooked as objects of serious study. But their time to shine has come — these stellar communities display remarkable diversity and harbor some of the universe's most intriguing characters. MARCIA BARTUSIAK

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One of the largest galaxies in our Local Group is the Pinwheel Galaxy, also known as M33. We now know what lies within its vast spirals — objects waiting for amateurs to observe. ALAN GOLDSTEIN

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In a good year, observers are lucky to catch the Ringed Planet gliding in front of one moderately bright star. But this month presents two golden opportunities: Watch a couple of 8th-magnitude stars flicker and disappear before your very eyes. ALISTER LING

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82 Super scope buyer's guide

If you are looking for that perfect holiday gift either for yourself or your loved one, the search is over. *Astronomy* reviews twenty-five tried-and-true telescopes that will delight newcomers and inspire seasoned observers. MICHAEL E. BAKICH



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B. SCHÖENING, V. HARVEYREU PROGRAM/NOAO/AURA/NSF

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JAY OUELLET

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ON THE COVER

The Milky Way Galaxy spirals its way through the Local Group of galaxies, innocently hiding violence behind its stately mask. Not only is our galaxy shredding minute dwarfs near it, absorbing them wholesale, but several billion years from now, it will spectacularly collide and merge with the Andromeda Galaxy. ILLUSTRATION BY DON DIXON



BOB AND JANICE FERA

www.astronomy.com/toc

THE LOCAL GROUP: Look into the future as the Andromeda and Milky Way galaxies collide.

ABSURD UNIVERSE: Learn how time has changed our view of the cosmos.

GLOBULAR CLUSTERS: Find the best observing targets.

FERA PHOTOGRAPHY: Bob and Janice answer questions about astrophotography in an on-line forum.

AND MUCH MORE ABOUT THIS ISSUE'S TOPICS

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Meet the (violent) neighbors

“He was such a quiet man,” say the neighbors about the recently discovered serial killer who lived nearby. Or so goes the urban legend. But that chilling realization of secreted violence is coming to light in an unlikely place: among the neighborly galaxies that surround us in space.

Enormous to us, yet insignificantly small compared with the myriad clusters of galaxies that litter the cosmos, our little neighborhood in space, the Local Group, consists of some 40 galaxies of varying shapes and sizes. Spanning 36 trillion million miles, the Local Group contains several ordinary, modest galaxies, as well as a slew of dinky dwarfs not much larger than bloated globular star clusters. The two big guys on the block are our own Milky Way, home to the Sun and 200 billion other stars, and our sister spiral the Andromeda Galaxy.

For years, a well-ordered picture of the local universe dominated astronomers' thinking. The Local Group was a happy, balanced place where galaxies slowly turned around each other in stately bliss. Yet recent research shows the Local Group is a violent, dynamic neighborhood in which the two big galaxies — bullies, really — are slowly shredding and absorbing the smaller galaxies one by one by one. That's what galaxies do — they consume each other.

Ray Villard, public information officer at the Space Telescope Science Institute, offers an intimate, up-to-the-minute portrait of this hostile family in “Order out of chaos,” on page 38. After reading it, you may not think of your home galaxy in the same way again. This is not your father's Local Group: It's a nasty, violent, merciless place.

World-renowned cosmologist Michael Turner of the University of Chicago offers his thoughts on the twisting road of cos-

mology in “Absurd universe” (page 44). What exactly is this dark energy stuff? How does it relate to dark matter? Why is the normal material in the universe, like us, such a small part of everything? Turner describes a golden age of cosmological research now upon us that soon may answer the biggest and boldest questions about the cosmos.

In “Great balls of fire” by Marcia Bartusiak (page 48), we learn that one constituent of the Milky Way, globular star clusters, also is undergoing a revolution in understanding. Once limited to the 150 such clusters in our home galaxy, astronomers now can use sophisticated sensors to peer deeply into nearby galaxies and study these balls of stars. Inhabited by ancient stars that have seen much of the history of the universe, globulars hold a telltale record of the unimaginably distant past. Teasing antiquity from distant globes of yellowish stars has become a fashionable — and important — part of astronomers' research.

As always, I invite you to contact me with comments about the magazine. E-mail me at editor@astronomy.com. I will always be listening.

Yours truly,

Dave Eicher
Editor



The Meade 30th anniversary sale

Buy a Meade telescope and receive a \$650 Meade Super Plössl eyepiece set for only \$99!



Now for a limited time, to celebrate Meade Instruments' 30 years in telescopes, you can buy a Meade telescope* and receive a full set of Meade premium-grade Super Plössl eyepieces for only \$99 additional. Never before have we made such an incredible offer available for such a wide range of our most popular telescope models.

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3. We will ship your eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed.

Other terms and conditions: Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add \$7.67 sales tax, for a total payment of \$106.67.** This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. after 8/15/02 and is subject to change without notice. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.



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Meade 14" LX200GPS-SMT Schmidt-Cassegrain, with standard-equipment Zero Image-Shift Microfocuser, Primary Mirror Lock, and Autostar II Controller; shown with optional 14" Superwedge.

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Facing page (right to left): Meade 7" LX200GPS-SMT Maksutov-Cassegrain; 8", 10", and 12" LX200GPS-SMT Schmidt-Cassegrains.

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(UHTC) Group: The optical coatings provided as standard equipment with Meade Schmidt-Cassegrains equal or exceed the reflectivity/transmission of virtually any coatings currently offered in the commercial telescope industry. Alternatively, however, the UHTC group is available optionally at the time of telescope purchase on Meade LX200GPS models and includes an exotic series of multi-layer coatings on the telescope mirrors and on the correcting lens. The UHTC group dramatically increases image brightness by about 20% across the visible spectrum. *Image brightness of the Meade 10" LX200GPS, for example, is effectively increased by about one full inch of aperture.* For a more thorough discussion of Meade's Ultra-High Transmission Coatings Group, please see our website at www.meade.com.

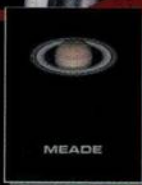
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primary mirror lock; 4-speed zero image-shift microfocus; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and 7-port multi-function control panel, including two RS-232 serial interface ports; manual and electric slow-motion controls on both axes; Autostar II control system with 3.5-Megabyte flash memory, digital readout display, permanently programmable Smart Drive and 185-speed drive controls on both axes, High-Precision Pointing, and GO TO controller; 145,000-object onboard celestial software library;* GPS alignment system with 16-channel GPS receiver, magnetic declination compensation, and true-level and North electronic sensors; 12VDC telescope power supplied from internal battery compartments accepting 8 (user-supplied) C-cells (optional 25 ft. cords available for powering from auto cigarette lighter plug or from 115VAC); 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12", 14"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12", 14"); Autostar Suite with imager/autoguider; Smart Mount; operating instructions. *A partial listing of Autostar II database libraries and numbers of objects includes:

New General Catalog (NGC)	7840
Index Catalog (IC)	5386
Uppsala Galaxy Catalog	12,940
Morphological Catalog of Galaxies	12,939
General Catalog of Variable Stars	28,484
SAO, Hipparcos, and Draper Star Catalogs	63,404
Yale Bright Star Catalog (BSC5)	6,150
Large Bright Quasars Survey (LBQS)	1055
Messier (M) and Caldwell Catalogs	219
Named Objects	227
Herschel Catalog	400
Abell Catalog of Galaxy Clusters	2712
Arp Catalog of Irregular Galaxies	645
Major planets from Mercury to Pluto	8



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Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate handbox for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrain of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centeration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries. \$249.95 (9.85)



Series 4000™ f/3.3 CCD Focal Reducer/Field Flattenor

Revolutionary 3-element Meade design permits ultrafast CCD imaging with increased edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to f/3.3 and f/5 SCT's to f/4. While significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. \$149.95 (5.26)

f/6.3 SCT's to f/2. Variable T-Adapter. Converts f/10 Schmidt-Cassegrain telescopes to f/3.3 and f/5 SCT's to f/4. While significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. \$149.95 (5.26)

Series 4000™ f/6.3 Focal Reducer/Field Flattenor

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture. \$129.95 (5.26)



2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of longer focal-length Barlows. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated. \$47.95 (4.54)

Series 4000™ 2x Apochromatic Barlow Lens #140:

The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm. \$79.95 (5.26)

Plössl 25mm Illuminated Reticle CCD Framing Ocular

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models: ST-4 through ST-8, AP1, AP2, and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror (above). Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyepiece; variable LED illumination control; batteries. 1.25". \$129.95 (4.54)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crosshairs reticle; rubber eyepiece. Wireless red LED illuminator and variable brightness control. 1.25". Batteries included. \$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. \$79.95 (5.26)

Series 4000™ Super Wide Angle

67° field; multi-coated



For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above. **Super Wide Angle** (SWA; 6-elements; 1.25"/2"): 13.8mm: \$139.95 (4.54); 18mm: \$149.95 (4.54); 24.5mm: \$179.95 (5.26); 32mm (2"): \$239.95 (7.02); 40mm (2"): \$299.95 (7.02)

Series 4000™ Ultra Wide Angle

84° field; multi-coated



The ultimate eyepieces: extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians. **Ultra Wide Angle** (UWA; 8-elements; 1.25"/2"): 4.7mm: \$169.95 (5.26); 6.7mm: \$199.95 (5.26); 8.8mm (1.25"/2"): \$239.95 (7.02); 14mm (1.25"/2"): \$299.95 (7.02)

CCD-Photo-Visual Flip-Mirror Systems

Use with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment for precise image centering; extra-fine helioid focusing of the eyepiece; extension tubes for 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.



#644 Flip-Mirror System: Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces. \$149.95 (7.02)

#647 Flip-Mirror System: Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7, or for visual applications with 1.25" or 2" eyepieces. \$249.95 (8.49)

#157 1.25" Adapter: Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.) \$15.00 (3.86)

World's Most Advanced Illuminated Reticle Eyepiece

Series 4000 Plössl 9mm, with rubber eyepiece and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. Internal batteries included. Bullseye reticle. 1.25". \$149.95 (6.14)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. \$129.95 (5.26)



MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyepiece; variable LED illumination control; batteries. 1.25". \$119.95 (4.26)

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The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyepiece. 1.25". \$219.95 (6.38)



Series 4000 Photo-Visual Color Filters (1.25")—Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

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Set #1—4 filters: #12, #23A, #58, #80A \$49.95 (4.54)
Set #2—4 filters: #11, #25A, #47, #82A \$49.95 (4.54)
Set #3—4 filters: #8, #21, #38A, #56 \$49.95 (4.54)

Series 4000 Moon Filter (#ND96): Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels. \$16.95 (2.73)

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For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces. \$49.95 (5.26)



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Meade-engineered for smooth, rapid focusing with ETX-90, -105, or -125. Four-speed operation from coarse to microfine. Standard-equipment hand controller accepts one 9v. (user-supplied) battery and focuses all ETX telescopes. Or focus through the telescope's Electronic Controller (EC) or through Autostar.

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Each supplied with #497 Autostar Controller and #884 Deluxe Field Tripod:

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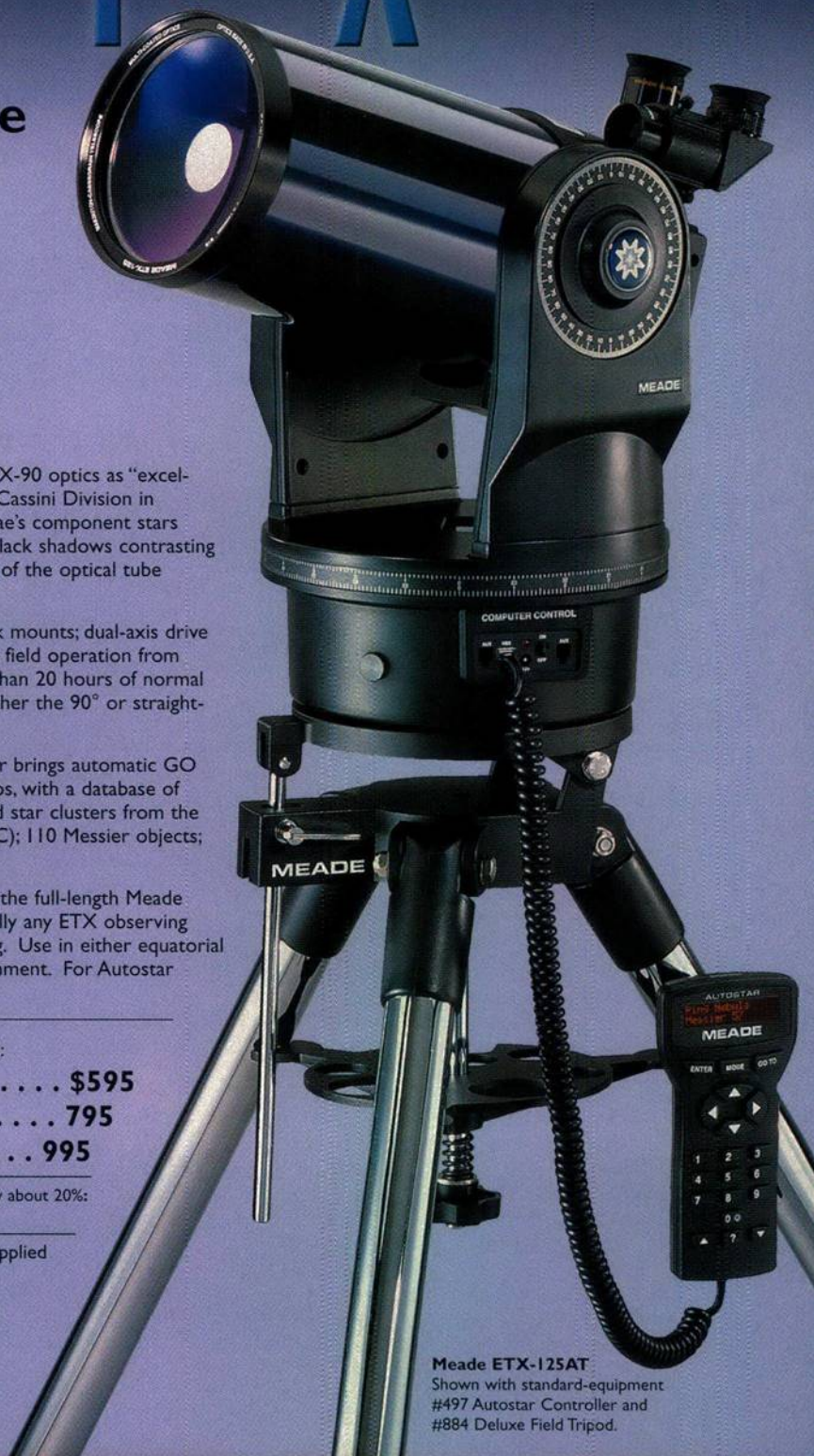


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1.25" - \$99.95 • Brandon 1.25" - \$99.95 • 48mm - \$199.95 • Visual Back SCT - \$199.95

LUMICON OXYGEN III FILTER

The renowned, original Lumicon OIII narrow bandpass filter (11nm) isolates just the two doubly-ionized oxygen lines (496 and 501nm lines) emitted by planetary and extremely faint nebulae. Produces near-photographic views of the Veil, Ring, Dumbbell and Orion nebula, among many other objects. You will be amazed at what the OIII filter allows you to see!

1.25" - \$99.95 • Brandon 1.25" - \$99.95 • 48mm - \$199.95 • Visual Back SCT - \$199.95

LUMICON HYDROGEN-BETA FILTER

The Lumicon H-Beta Filter isolates only the Hydrogen-Beta line of the spectrum (486.5nm). Now you can view extremely faint, special objects such as the Horsehead, Cocoon and California Nebulae. In many cases, the Lumicon H-Beta Filter is the ONLY way to view these objects. A steady, transparent sky, with a minimum of an 8" or larger instrument, combined with the Lumicon H-Beta Filter, all make an unbeatable combination for viewing those "notch in the belt" objects.

1.25" - \$99.95 • Brandon 1.25" - \$99.95 • 48mm - \$199.95 • Visual Back - \$199.95

LUMICON HYDROGEN-ALPHA PASS FILTER, FOR BLACK AND WHITE DEEP-SKY PHOTOGRAPHY

The Lumicon H-Alpha Pass Filter is a powerful photographic aid in overcoming light pollution during deep-sky photography, and will help you achieve strikingly improved results in telephoto lens B&W astrophotography. It is ideally matched to hypersensitized 2415 film, and will reduce light pollution 10-fold, making it ideal for photography of faint emission nebulae.

Transmission for this sharp-cut-off filter is zero below 630nm, 90% at Hydrogen-Alpha 656nm, and 90-98% from 656nm to the near infrared. Both surfaces of filter have high-efficiency anti-reflection coatings to boost performance.

Exposures may be increased 2-10 times with the H-Alpha Pass Filter, depending on the faintness of the nebula. 48mm - \$69.95 • 58mm - \$79.95 • 77mm - \$89.95 • 82mm - \$99.95

48MM COLOR FILTERS

Used in lunar and planetary observing.

Red - \$29.95 • Orange - \$29.95 • Yellow - \$29.95 • Green - \$29.95 • Blue - \$29.95 • Ultra-Violet (Clear) - \$29.95 • Polarizer - \$49.95 • Neutral Density - \$39.95

1.25" lunar & planetary photo-visuals, world's best, coming soon.

LUMICON MINUS VIOLET FILTER FOR COLOR OR BLACK AND WHITE PHOTOGRAPHY

The Lumicon Minus Violet Filter greatly improves photographs taken through lens systems, producing pinpoint star images. It is especially recommended for all telephoto lenses. This filter is made from optically flat specially-made colored glass, and has anti-reflection coatings on both surfaces.

Recommended Films

All films can be used with the Minus Violet Filter; hypersensitized 2415 is the recommended B&W film, and is available directly from Lumicon or from any of Lumicon's authorized dealers.

Visual Use

The Minus Violet Filter can eliminate or greatly reduce the blue halo sometimes seen around stars through refracting telescopes. It is ideal for observing the moon and planets.

48mm - \$49.95 • 58mm - \$59.95 • 72mm - \$69.95

LUMICON INFRARED BLOCKING FILTER

The Lumicon Infrared Blocking Filter completely blocks all infrared light above 750nm. Its versatile, anodized aluminum cell has 42mm male T-threads on one side and 48mm male threads with 42mm female T-threads, internal, on the other. Great for CCD camera infrared blocking purposes.

2" - \$99.95

Infrared Blocking Filter 1.25" coming soon.

LUMICON UV DUST SEAL FOR MOST SCTs

The Lumicon UV Dust Seal keeps dust and insects out of your telescope. The seal mounts on the back of your SCT and accepts all attachments. It is an ultraviolet filter that passes all visible wavelengths of light with minimal absorption, no aberration, and no noticeable internal reflections. Fully Multi-Coated.

5-9.25" SCT / Mak - \$39.95 • Meade 10/12/14" - \$89.95 • Celestron 11/14" - \$89.95

LUMICON COMET BAND FILTER

Lumicon's narrow visible bandpass (25nm) Comet Band Filter isolates the 501nm OIII and the 514nm Cyanogen lines. The high contrast gain of the filter reveals the delicate ionized tail of gaseous comets, allowing you to see their full extent. The Comet Band Filter also helps you to better distinguish gaseous comets from dusty comets which show little contrast gain. For dusty comets, use the Lumicon Deep Sky Filter.

Howard Brewington, famed comet discoverer says: "I discovered Comet Aarseth-Brewington, 1989a1, using the Lumicon Comet Band Filter. The filter doubled the contrast, making the comet very easy to spot." Be the person to discover the next "Comet of the Century" using the Lumicon Comet Band Filter.

1.25" - \$99.95 • Brandon 1.25" - \$99.95 • 48mm - \$199.95 • Visual Back - \$199.95

SOLAR PROMINENCE FILTERS

The 1.5 Ang. Lumicon Solar Prominence Filter system lets you see the awe-inspiring solar prominences jutting off the edge of the sun. Sunspots and bright filaments can also be seen on the sun's surface. The filter has a 2" barrel for insertion into 2" focusers, and can be easily adapted for 1.25" eyepieces.

Solar Prominence Filter \$699.95 • 58mm Energy Reject Prefilter - \$169.95 • 77mm Energy Reject Prefilter - \$199.95

Off-Axis Mask for 8" SCT - \$69.95 • Off-Axis Mask for Meade 10" - \$89.95 • Off-Axis Mask for C11 - \$99.95 • Off-Axis Mask for 12" LX200 - \$99.95 • Off-Axis Mask for C14 - \$119.95 • Off-Axis Mask for M14 - \$119.95 • Off-Axis Mask for 16" LX200 - \$129.95

MULTIPLE FILTER SELECTOR

The Lumicon 1.25" Multiple Filter Selector lets you switch instantly back and forth between your Lumicon 1.25" filters without having to constantly thread and unthread them from your eyepieces. You may leave one of the 5 slots open to compare filtered and non-filtered views. - \$129.95

EASY GUIDERS

All of Lumicon's famous off-axis guiders feature Lumicon's patented radial and rotational off-axis adjustments - combined with a large off-axis pick-off prism, making bright guide star selection a breeze.

CASSEGRAIN EASY GUIDER FOR 7" TO 9.25" SCTs

The Lumicon Cassegrain Easy Guide allows off-axis guiding with your Cassegrain telescope, reducing the f-ratio from f/10 to f/6.3 with a large, fully-coated focal reducing lens. The faster f-ratio, combined with the ease of finding and guiding on bright guide stars, minimizes guiding error, making for successful astrophotos. Threaded for 48mm filters. Specify camera type when ordering.

Celestron 5 - \$249.95 • 7" Mak - \$249.95 • 8" SCTs - \$249.95 • Celestron 9.25" - \$249.95

GIANT EASY GUIDER FOR 10" TO 16" SCTs
The Lumicon Giant Easy-Guider is a powerful photo/visual tool, utilizing an 80mm multicoated compression lens, reducing the f-ratio from f/10 to f/6.3, allowing you to take full advantage of your telescope's capabilities. Ideal for 35mm and 120 format film with 100% edge-to-edge illumination and pinpoint star images. All other off-axis guiders have prisms and focal reducing lenses a fraction the size of the Lumicon Giant Easy-Guider's. Threaded for all Lumicon 48mm filters. Specify camera type when ordering.

10", 12", 14" and 16" Meade - \$399.95 (Meade 16" LX200 requires adapter - \$169.95) • 11" and 14" Celestron - \$399.95

NEWTONIAN AND REFRACTOR EASY GUIDER

The Lumicon Newtonian and Refractor Easy Guiders allow off-axis guiding directly through the main telescope, thus preventing differential flexure between telescope and guide scope that can ruin your astrophotos. Low-profile design installs in seconds into 1.25" and 2" focusers. Threaded for 1.25" and 48mm filters. Specify camera type when ordering.

1.25" and 2" Newtonian - \$189.95 • 1.25" and 2" Refractor - \$189.95

LUMICON EASY GUIDER ACCESSORIES

- Newtonian Easy-Guider Focal Reducer Lens in Cell - \$79.95
- Giant Easy-Guider Focal Reducer Lens in Cell - \$199.95
- Giant Easy-Guider - No Lens - \$319.95
- Cassegrain Easy-Guider - No Lens - \$219.95

LUMICON 3X RELAY DIAGONAL FOR USE WITH EASY GUIDERS

Lumicon Relay Diagonal's 3x Barlow lens increases the guiding magnification in the off-axis portion of your Lumicon Easy-Guider, increasing off-axis guiding ease and precision. - \$99.95

HYPER KITS

LUMICON FILM HYPERSENSITIZATION KITS

Film hypersensitization with a Lumicon Hyper-Kit super-dries your film's emulsion using nitrogen and hydrogen (Lumicon's Forming Gas: 8% prepurified hydrogen, 92% prep. nitrogen, removing ALL water vapor and oxygen molecules, thus thermally stabilizing the film's emulsion. The process also 'soaks' the emulsion with hydrogen, thus sensitizing the silver halide crystals, making them more sensitive to faint light. The combined effect reduces reciprocity failure of the film, allowing it to remain sensitive to light well beyond an hour instead of only a few minutes. Hypered film is a MUST for anyone who is serious about taking deep-sky photographs.

LUMICON MODEL 300 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

For simplest hypering with film still in its metal cassette, the Model 300 Hyper-Kit is easy in use and safe for your film. Operates with Lumicon's Forming Gas at 30° C. Hyper film in two to five days.

Chamber Only - \$249.95 • Film Hyper Kit - \$375.95 • Hyper Kit O-Ring Set - \$9.95

LUMICON MODEL 600 FILM HYPERSENSITIZATION KIT FOR 35MM AND 120 FILM

The versatile Lumicon Model 600 Hyper-Kit is capable of hypering film either while still in its metal cassette at 30° C, or more quickly with highest saturation on the open reel at 50° C. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas.

Chamber Only - \$299.95 • Film Hyper Kit - \$475.95 • Hyper Kit O-Ring Set - \$9.95 • Hyper Kit Hand Vacuum Pump - \$39.95 • Hyper Kit Vacuum Pump Handle - \$9.95

LUMICON MODEL 1200 FILM HYPERSENSITIZATION KIT FOR 35MM, 120, AND 4x5 FILM

Large-capacity Lumicon Model 1200 Hyper-Kit accepts 4x5 film. Kit is capable of hypering film in just 12-to-20 hours with highest saturation. Super-dries and sensitizes the film's emulsion with Lumicon's Forming Gas at either 30° or 50° Centigrade for simple or advanced modes of operation.

Chamber Only - \$379.95 • Film Hyper Kit - \$751.95 • 4x5 Plate Holders - \$99.95 • Hyper Kit O-Ring Set - \$9.95

HYPER KIT ACCESSORIES

- 4x5 Sheet Film holder - \$99.95
- 35L Cylinder of Forming Gas - \$145.95
- 30° C Temperature Sensor Probe - \$99.95
- 50° C Temperature Sensor Probe - \$99.95
- Temperature Controller - \$139.95 • Electric Vacuum Pump - \$349.95 • 220 V option on Vacuum Pump - \$44.95 • 220V/110V Converter - \$29.95 • Vac/Pressure Hose with Clamp - \$9.95

ASTROPHOTOGRAPHY FILM

HYPERED FILMS

Use Lumicon Hypersensitized Film to take stunning astro photographs. Allows you to expose film on your favorite deep sky object far longer, with no fog buildup, than does non-hypersensitized film.

Fuji G800 - \$19.95 • Fuji RD100 - \$14.95 • TP2415 B&W - \$19.95 • TP6415, 120 - \$19.95 • Kodak P1600 - \$24.95 • Kodak PPF400 - \$19.95 • Kodak PPF400, 120 - \$19.95

NON-HYPERED FILM

Lumicon's high-contrast, extremely fine-grained film. High quality for medium-format astrophotography.

TP2415, Bulk 150' Roll - \$79.95 • TP2415, Normal 36 exposure - \$11.95 • TP4415, 4x5 Normal 25 Sheets - \$49.95 • SO-219 Vericolor Slide Film - \$14.95 • Kodak 6415, Normal Film - \$9.95 • Fuji G800, Normal Film - \$9.95 • PPF400, 120, Normal Film - \$11.95 • PPF400, 120, Normal Film - 5 pack - \$49.95 • Kodak P1600, Normal Film - \$19.95 • Fuji Sensia RD100, Normal Film - \$9.95

FILM DEVELOPING MATERIALS

- Film Changing Bag - \$16.95
- Kodak D19 B&W Developer - \$19.95
- Patterson film developing tank - \$19.95

DIAGONALS

ENHANCED ALUMINUM STAR DIAGONALS

The Lumicon Enhanced Aluminum Star Diagonal reflects 96 to 97 percent of the light from the telescope's primary optics into your eyepiece. Its single 1/10 wave precision-polished surface is superior to the three surfaces of prism diagonals, and its enhanced coating is more durable than a standard aluminum coating. Lumicon collimates each star diagonal using a double-pass collimator, ensuring that the light reflected from the diagonal is perfectly perpendicular to the telescope's optical axis.



LUMIBRITE STAR DIAGONAL

The Lumicon LumiBrite Dielectric-Coated

Diagonal reflects >98 percent of the light from the telescope's primary optics into your eyepiece. Not only is the Dielectric Coating more durable than a standard aluminum coating, it is also smoother, resulting in higher image contrast. 1.25" - \$149.95 • 2" - \$239.95

SKY VECTOR



The Lumicon Sky Vector is a state-of-the-art digital setting circle system, providing virtually any astronomical telescope, whether equatorial or altazimuth, with a continuous, real-time digital readout of right ascension and declination coordinates. With the Sky Vector, you will be able to find objects even faster than with most fully computer-driven telescopes. Its alphanumeric display uses a simple, easy-to-read scrolling text format.

There is no need to polar align or to enter Latitude, Longitude, Date, Altitude, and Siderial time - just initialize on one or two stars and you're ready to go!

SKY VECTOR 1

The Lumicon Sky Vector 1 features: One- or two-star initialization; 4000-step encoders for high-resolution accuracy (0.09 deg.); Digital Right Ascension coordinate readout to 1 minute; Digital Declination readout to 10 arc-minutes; Guide mode for guiding you to the selected object in current memory; Database containing over 220 of the finest objects in the sky, including the famed "Messier Catalog." Complete Set - \$349.95 • Kit only - \$269.95

LUMICON NGC SKY VECTOR

The Lumicon NGC Sky Vector has all the features of the Sky Vector 1, plus a large 12,000-object database, higher resolution display modes, IDENTIFY mode, and current constellation and chart number displays - all on a 16-digit red LED display. It can be integrated with a personal computer for display of celestial object coordinates.

Complete Set - \$489.95 • Kit only - \$419.95 • Serial Cable - \$29.95

SKY VECTOR UPGRADES

- Upgrade 3.65 Chip Set for NGC Sky Vector. - \$59.95
- 8192-Step Encoder (Set of 2). Can be purchased separately or in place of the standard 4000 step encoders. - \$29.95

LUMICON SKY VECTOR HARDWARE PACKAGES

Lumicon Sky Vector Hardware Package for Meade and Celestron SCTs includes: declination encoder bracket, right ascension encoder holder, encoder shaft holders, Allen wrench, and instructions.

Lumicon Sky Vector Hardware Package for Dobsonian telescopes includes: brass azimuth bolt, stainless steel azimuth encoder bracket, aluminum altitude-encoder-shaft holder, stainless steel altitude encoder bracket, 10 wood screws, Allen wrench, and instructions.

- C5+ - \$79.95 • C8 - \$69.95 • Celestar 8 - \$79.95 • Celestar 8 Dlx - \$79.95 • G8/G11 - \$349.95 • Ultima 8 - \$79.95 • Ultima 11 - \$99.95 • C11 - \$79.95 • C14 - \$129.95 • Meade 2080 - \$69.95 • 2120 - \$79.95 • 8" Dob - \$69.95 • 10" Dob - \$69.95 • 12/13" Dob - \$79.95 • 16/17" Dob - \$89.95 • C1700 - \$299.95

RICHFIELD VIEWERS

RICHFIELD VIEWER FOR 7" TO 9.25" SCTs

The Lumicon Richfield Viewer takes your Schmidt-Cassegrain's f/10 optics and reduces them to f/6.3 for beautiful wide-field views. Its fully-coated 50mm diameter



focal reducing lens has a larger clear aperture and less coma than higher-priced focal reducers on the market, providing superb unvignetted views. Barrel accepts 2" star diagonals. Comes with an aluminum 2"-1.25" eyepiece reducer, threaded for 48mm filters. - \$99.95

RICHFIELD VIEWER, THREADED FOR 7" TO 9.25" SCTs

Threads directly into telescope. - \$99.95

RICHFIELD VIEWER, SLIDE-ON, FOR 7" TO 9.25" SCTs

For attachment onto SCTs that have the Lumicon Easy-Guider threaded attachment ring in place. Slides over attachment ring. - \$99.95

GIANT RICH-FIELD VIEWERS

LUMICON GIANT RICH-FIELD VIEWER FOR LARGE SCTs

Takes your large Schmidt-Cassegrain f/10 optics and reduces them to f/6.5 for the widest possible views of large galaxies like M31, M33 and NGC 253, and pairs of galaxies like M81 and M82. Moving the 80mm diameter focal reducing lens to the forward position in the Rich-Field Viewer body yields an even wider field. Comes with a 2"-1.25" eyepiece reducer, threaded for 48mm filters.

10" SCTs - \$279.95 • Celestron 11" - \$279.95 • 12" SCTs - \$279.95

LUMICON 2.5X CCD COMPRESSOR

This cost-effective, fully-coated lens widens the telescope field and yields pinpoint star images for small to medium-size CCD cameras. Has male threads for standard 1.25" eyepieces or camera-type barrels. - \$129.95



LUMICON 48MM COMA CORRECTOR/FIELD FLATTENER FOR NEWTONIAN EASY GUIDER OR 2" EYEPIECE

The Lumicon Coma Corrector / Field Flattener Lens dramatically reduces coma and flattens the field when used, in particular, with f/3.5 to f/6 Newtonian telescopes. It makes off-axis star images much smaller, thus improving photographic quality and making guiding much easier. Free of all chromatic aberration and fully multiccoated to prevent ghost images. Can be used on all 48mm threaded accessories. Neither shrinks nor magnifies the image. - \$239.95

LUMICON 1.5x-1.8x MULTIPLIER/FIELD FLATTENER

The Lumicon Multiplier / Field Flattener Lens has been custom computer-designed to increase image scale with the flattest field possible for photography and visual use with fast Newtonian Telescopes. This lens is suitable for use with f/3.5 to f/6 systems. Fully multiccoated for maximum light transmission. - \$259.95

FINDERSCOPE

Lumicon 80mm SuperFinder for Right-Angle viewing. This finder telescope actually lets you see many of the deep-sky objects you are looking for, complementing any telescope having 8 or more inches of aperture. It also makes for a wonderful rich-field telescope for beautiful views of the Milky Way. Comes with 25mm, 1.25" cross-hair eyepiece and helical drawtube-type focuser.

50mm RA Finder - Body Only - \$79.95 • 50mm RA Finder - Body Only - \$79.95 • 50mm Straight-Thru Finder - complete - \$119.95 • 80mm Right Angle SuperFinder - Body Only - \$199.95 • 80mm Right Angle SuperFinder with Tripod Block - \$219.95 • 80mm Right Angle SuperFinder - Complete - \$299.95 • 80mm Straight-Thru SuperFinder - Body Only - \$199.95

FINDERSCOPE BRACKETS

This two-ring finder bracket firmly holds finderscopes to your telescope while allowing precise alignment with the main optical axis. The base is radius-cut to fit snugly against the telescope's main tube, and the dovetail groove makes it easy to install or remove the finderscope from the base. Fastens in brand name SCT telescope mounting holes.

- 50mm Finder Bracket, 8", 10/11", and 14" - \$49.95
- 80mm Finder Bracket, 8", 10/11", and 14" - \$59.95

• Universal Dovetail Bracket for 50mm finder - \$39.95

- 2 traditional universal ring-type brackets for 50mm finder - \$19.95

LUMICON 25MM CROSS-HAIR FINDER EYEPIECE

This well-made 25mm, 1.25" Kellner single-crosshair finderscope eyepiece is ideally suited for Lumicon's 50mm and 80mm SuperFinders. High contrast and flat field. Non-illuminated. - \$69.95



GUIDING EYEPIECE



LUMICON GUIDING EYEPIECE WITH RETICLE ILLUMINATOR

Lumicon's top-quality 12.5mm, 1.25" Orthoscopic eyepiece with focusable dual cross hair for precision guiding. Incorporates new state-of-the-art cordless Reticle Illuminator, featuring rheostatic brightness control and on/off switch. 12.5mm, 1.25" Illuminated Reticle E.P. - \$149.95 • Pulseguider Illuminator - \$42.95

BINOVIEW

LUMICON BINOVIEW

These new high-quality German-made binoviewers employ Grade-A BK 7 crown glass for its precision-polished prisms. Ordinarily, BaK 4 is used as a recourse to improve color correction, but in these binoviewers color correction is so good that we may use the most transparent, homogeneous, bubble-free crown glass available - BK 7. Clear aperture is 22mm. Its straight-through design employs superior roof prisms for image erection. Each prism surface is multiccoated for the highest transmission of light and freedom from ghosts. Focuser travel is 20mm. - \$699.95

VISUAL AND PHOTOGRAPHIC ACCESSORIES

PHOTOGRAPHIC ADAPTERS

1.25" Prime Focus Adapter - \$24.95 • 2" Accessory Adapter for Celestron Classic Refractors - \$39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors - \$39.95 • .96" Prime Focus Adapter - \$19.95 • Basic Camera Adapter 1.25" - \$39.95 • Basic Camera Adapter .965" - \$39.95 • Adapter to mount Mamiya 645 Camera to 2" - \$149.95 • 2" to T-thread adapter - \$29.95 • Tele-Extender - \$29.95

VISUAL ADAPTERS

1" Thread-in extension tube, 1.25" - \$19.95 • 1.25" Focuser to .96" Eyepiece Adapter - \$24.95 • 2" Length Drop-in Extension Tube 1.25" - \$19.95 • 4.5" Length Drop-in Extension Tube, 1.25" - \$29.95 • 2" Long Thread-in Extension tube, 2" Diameter - \$24.95 • 2" Long, 2" Diameter Drop-in Extension Tube - \$24.95 • 3" Long, 2" Diameter Drop-in Extension Tube - \$24.95 • 1.25" Reducer - \$24.95 • 2" Accessory Adapter for C6 - \$39.95 • 2" Accessory Adapter for Schmidt Cassegrains - \$39.95 • 2" Accessory Adapter for Celestron Classic Refractors - \$39.95 • 2" Accessory Adapter for Celestron Fluorite Refractors - \$39.95 • Adapter for .96" focuser and 1.25" Eyepiece - \$24.95 • 1/10 Viewing Adapter for Giant EasyGuider - \$89.95 • Adapter for Meade 2" Thread-on diagonal to Cass. Easy Guider - \$39.95 • Adapter for Meade 2" Thread-on diagonal to Giant Easy Guider - \$49.95 • Adapter to hold 1.25" Eyepiece on T-thread - \$29.95 • Adapter to hold 2" eyepiece on T-thread - \$49.95

EASY GUIDER ADAPTERS

Adapter to mount Hasselblad Camera to Giant Guider - \$449.95 • Adapter to mount Pentax 645 Camera to Giant Guider - \$169.95 • Adapter to mount Pentax 6x7 Camera to Giant Guider - \$149.95 • 16" LX200 adapter for Giant Guider - \$169.95 • Adapter to mount Hasselblad Camera to Cass. Easy Guider - \$349.95 • Adapter to mount Pentax 645 Camera to Cass. Easy Guider - \$159.95 • Adapter to mount Pentax 6x7 Camera to Cass. Easy Guider - \$139.95

STEP RINGS

48mm to 46mm - \$11.95 • 48mm to 49mm - \$11.95 • 49mm to 48mm - \$11.95 • 52mm to 48mm - \$11.95 • 52mm to 58mm - \$11.95 • 55mm to 48mm - \$12.95 • 55mm to 58mm - \$12.95 • 58mm to 48mm - \$12.95 • 62mm to 58mm - \$12.95 • 62mm to 72mm - \$14.95 • 67mm to 62mm - \$15.95 • 67mm to 72mm - \$15.95 • 72mm to 67mm - \$15.95 • 72mm to 77mm - \$15.95 • 77mm to 72mm - \$15.95 • 77mm to 72mm - \$15.95 • 82mm to 77mm - \$15.95

LUMICON ADJUSTABLE PIGGYBACK MOUNTS

Lumicon Deluxe Piggyback Mounts allow you to mount the Lumicon SuperFinder, other small telescopes, or cameras having 14-20 threaded mounting blocks, onto medium and large telescopes. The Piggyback Mounts are adjustable in altitude and azimuth, thus allowing you to align your optics with the optics of your main telescope. Each of the four available Piggyback mount bases have their own radius cut, allowing a solid flush mount to your telescope's main tube.

6" - \$59.95 • 8" SCT - \$59.95 • 10/11" SCT - \$59.95 • Celestron C14 - \$59.95

MISCELLANEOUS ACCESSORIES

HELICAL FOCUSERS

Lumicon Helical Focuser, 1.25" and 2.00" for tube O.D.s 7.5", 9.5", 12.5", 16", and 20". Also flat base or specially for Odyssey.

1.25" Helical Focusers 7.5" - \$69.95 • 1.25" Helical Focusers 9.5" - \$69.95 • 1.25" Helical Focusers 12.5" - \$69.95 • 1.25" Helical Focusers 16" - \$69.95 • 1.25" Helical Focusers 20" - \$69.95 • 2.00" Helical Focusers, Flat Base - \$69.95 • 2.00" Helical Focusers, Odyssey - \$69.95 • 2.00" Helical Focusers 7.5" - \$99.95 • 2.00" Helical Focusers 9.5" - \$99.95 • 2.00" Helical Focusers 12.5" - \$99.95 • 2.00" Helical Focusers 16" - \$99.95 • 2.00" Helical Focusers 20" - \$99.95 • 2.00" Helical Focusers, Flat Base - \$99.95 • 2.00" Helical Focusers, Odyssey - \$99.95

VINYL DUST COVERS AND PLUGS

1.25" - \$6.95 • 1.3" - \$8.95 • 1.5" - \$8.95 • 2" - \$6.95 • 2.1" - \$7.95 (all these prices for a set of four) • 5.5" - \$7.95 • 6.7" - \$9.95 • 7.5" - \$12.95 • 9.5" - \$17.95 • 10.3" - \$17.95 • 12.5" - \$23.95 • 12.8" - \$23.95 • 15" - \$35.95 • 15.6" - \$36.95 • 16" - \$37.95 • 19" - \$42.95 • 21" - \$45.95 • 1.25" Plastic Dust Plug - \$6.95 • 2" Plastic Dust Plug - \$8.95 • 3.5" Plastic Dust Plug - \$6.95 (all these prices for each piece).

LUMICON LUMILITE RED LED FLASHLIGHT

The Lumicon Red LED Flashlight not only provides the proper illumination for star atlases, but also for walking in the dark when held at or below belt level. Has built-in resistor for energy conservation - If you accidentally leave it on when you pack up, its batteries will still be almost as good as new in the morning! Great for astronomers, submariners or pilots who need to preserve their night vision. - \$14.95

BARLOWS

Lumicon 2x Barlow 1.25" - \$39.95
Lumicon 2x Barlow 1.25" Thread-in - \$79.95

12" CAMERA CABLE RELEASE

Self-locking 12" Camera Cable Release for timed exposure. This high quality vinyl-covered cable release prevents camera shutter vibrations on long exposure photographs - a must for astrophotography. - \$19.95

COLLIMATORS

Lumicon Cheshire Collimator for Laser - \$39.95

LUMICON 6X CRITICAL FOCUS SCOPE, HAND-HELD

This simple accessory will magnify by 6x stars that are seen through your camera's viewfinder, allowing you to more easily determine when best focus has been achieved. - \$19.95

DIAGONAL MIRRORS

1/10 wave flatness, fine-annealed low-expansion Pyrex. ENHANCED Aluminum >96% reflectivity. 1.33" - \$49.95 • 1.55" - \$59.95 • 1.83" - \$79.95 • 2.60" - \$129.95 LUMIBRITE Dielectric Coating >98% 1.33" - \$99.95 • 1.83" - \$149.95

FILTERS AND LENS CLEANING KIT

Includes: cleaning fluid, lens cleaning tissue, Ultra Brush Dust Remover, blower brush, Q-Tips - \$19.95

HOW TO ORDER

You can order online; please visit our website at www.lumicon.com, or you can order direct from us by calling 805/520-0047, 800/420-0255 or fax 805/520-3030; Credit Card accepted. You can also buy Lumicon products by visiting the showroom of your favorite authorized Lumicon astronomy retailer. All products are subject to shipping and handling charges and sales tax if applicable. Please call us or visit Lumicon's website for more details.

LUMICON

Lumicon International
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Risky business

“Trial by fire” by Bob Berman (July 2003) really caught my attention. The article was interesting, but I disagreed with the author throughout most of it. It was irritating that someone thinks this is an appropriate time to rehash the past tragedies of the space program.

NASA has done an amazing job, and I think they need to be congratulated instead of made to look like fools. This is a time to look at all the successes in attempting to expand our world.

Berman says NASA researchers are wise, but he makes them look like blundering idiots. It sounds almost as if he blames them for the shuttle not being safe. Engineers are given a budget, which means they have to make tradeoffs. At some point, another million dollars is not going to make the shuttle safer. The people at NASA are not fools; they are just making very difficult decisions within the means they are given.

I agree with Berman that people remember only the tragedies regarding space exploration. We have had some setbacks over the forty-plus years of the space program, but I want to remind everyone that we are expanding our universe, and overall, I think it has been a huge success.

— JAMES MCCALL, MANASSAS, VIRGINIA

I was glued to “Trial by fire,” but I am troubled by one section. Berman clearly indicates recordings of the astronauts “within the doomed, plummeting capsule” exist. I was horrified by the thought — and I was suspicious.

If it is true that NASA possesses any recordings beyond Challenger pilot Michael Smith’s now somewhat famous “uh oh,” I have not been able to find evidence of it from reputable news organizations in print or on-line. In fact, the web site referenced by your magazine in regard to the article, history.nasa.gov, makes it a

point to crush this myth. I am left to wonder if Berman is making this up to add some (inappropriate) juice to what should be a somber, truthful, article.

— DEAN MITCHEL, CARSON CITY, NEVADA

The July edition of *Astronomy* was the best I have ever read. I saved the best for last: Bob Berman’s article. I grew up with the space program and have celebrated its successes and agonized with its failures.

Berman handled the subject matter in “Trial by fire” with respect for the fallen heroes from all countries but added his wonderful sense of humor in a truly delightful manner.

— FRANK FILEMYR, PRIEST RIVER, IDAHO

Expanding universe

In 1998, scientists stated that the expansion of the universe is accelerating. This was most puzzling since a “Big Bang” concept for the beginning of the universe should result in a gradual slowing of expansion. The amount of dark matter would determine if the universe would eventually come to a halt and begin to shrink or would simply continue to expand forever, albeit at a slower rate.

No one seems to be questioning this new “fact,” but I think a healthy dose of skepticism is important whenever a startling revelation occurs. What astronomers are not stating here is that their conclusion is based on measurements of the change in the wavelength of light, i.e., the Doppler effect. There is no question that the Doppler effect is real over modest distances. However, if the Doppler effect is



THE FIRST SHUTTLE, Columbia, launched on April 12, 1981, inaugurating a new era of space flight replete with tragedies and triumphs. NASA

not correct over large distances, one must be careful about drawing conclusions from these measurements.

— JACQUES GUERTIN, NEWARK, CALIFORNIA

Postscript

The Universe (Universe Productions, Menlo Park, California, 2002), which was featured in Book Reviews (August 2003), is available on DVD or VHS and can be ordered at www.universedvd.com or by calling toll-free, 888.955.1995 (9–5 PST).

— ASTRONOMY EDITORS

We welcome your comments. Send letters to *Astronomy Letters*, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.

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Left in the dark

We're born and we grow up to find ourselves staring into an amazing, if perplexing, universe wondering: What is this place? It's a question that probably hasn't changed since humans first developed brains large enough to be tormented. ◀ A millennium ago, we were satisfied with wacky explanations like Earth being encircled by

crystalline spheres. Even by the time John F. Kennedy occupied the White House, astronomers still couldn't rule out the idea that the universe had always existed as it does today. At the time, most people believed the cosmos had some sort of birth between 12 and 20 billion years ago. Today, evidence strongly supports such a genesis and sharply pegs it 13.7 billion years in the past.

This precise estimation doesn't preclude other universes of unknown ages from coexisting with ours (a longtime favorite model for Russian cosmologists), and it doesn't prevent the absolute meta-universe from being timeless and birthless. Obviously, we can discuss only what we can observe.

The biggest difference between those old competing outlooks was one of evolution. In a "steady state" model, the universe expands, but new atoms pop into existence and form new stars and galaxies, keeping things pretty uniform everywhere.

In a Big Bang model, the past appears very different from the present because the universe changes. You can't mistake one model with the other.

We probably wouldn't be able to decide between competing models if the speed of light were infinitely fast because then, the whole universe would look the same everywhere. But light from distant galaxies takes ages to arrive here, so a galaxy 10 billion light-years away is seen as it was 10 billion years ago. It's not too hard to compare this ancient light to nearby galaxies, like Andromeda, that are essentially viewed in the present era.

Using this method of comparison, it became obvious by the 1970s that the entire universe evolves over time. Far-off galaxies tended to be bluer (meaning they had heavier, younger stars) and were more predominantly spiral than those we see in our own era. More galaxies were colliding back then, too. It was a wonderfully violent, irresponsible time, those Wild West days of the cosmos.

Earlier this year, researchers using the Hubble Space Telescope and the Chandra X-ray Telescope reported more evolutionary news. It seems that galaxies steadily increased in size during the first seven billion years of the universe's life. That era also was characterized by rapid star formation everywhere. Gravity ruled during that entire period, slowing down the universe's growth.

Then, some six billion to seven billion years ago, when the universe was half its present age, everything changed. Star formation quickly dropped to just 1/10 of its former rate, while the universe reversed its previous braking and started to increase its dimensions at an ever-accelerating pace. It was as if the force of gravity suddenly lost its dominance to a different, outward-pushing force, a sort of anti-gravity. An epic development — and a weird one.

It takes a lot of power to blow a universe apart, and because energy and matter are different sides of the same coin, the mysterious outward-pushing force has to be the biggest component of the universe. Originating in Einstein's theory of relativity, this force came to be called the "cosmo-

logical constant," which does nothing whatsoever to explain what it is.

Meanwhile, on smaller distance scales, our galaxy and all others spin way too fast. They also hang out so closely with neighbors there must be five to ten times more gravity than can be produced by their inventory of stars, gas, and anything else we can think of. Known for three quarters of a century, this strange, invisible glue presumably comes from huge amounts of an unknown material that generates gravity but cannot be seen. Astronomers refer to it as "dark matter," which also is not particularly helpful.

In some ways, we've made great progress. When it comes to probing planets and stars, and understanding the clockwork laws that govern the cosmos, we're in the fast lane. We now know the age of the observable universe and have solid theories about what unfolded during the first fraction of a second after the Big Bang. We've identified 4 percent of the universe's contents as the familiar forms of energy and matter that comprise everything from burgers to Betelgeuse. We can only guess at the remaining 96 percent. We've named it dark matter or dark energy but have little understanding of either. We don't know why the Big Bang happened or what event (if any) preceded it.

We know Earth doesn't rest on a giant turtle, yet we have more questions than ever before. And they're deeper head-scratchers than the previous ones. So, while it's an exciting time for every branch of astronomy, cosmologists still seem to be in over their heads. Like a weird dream where the hallway stretches as you race toward the far end, cosmologists appear condemned never to get closer to answering those basic questions: What is everything? And, where did it all come from?

But we'll hang in there. We've already invested a few hundred thousand years. What's a few more? ■

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Attention holiday shoppers

Over the years, I've received a lot of requests for advice on selecting a suitable telescope for the novice astronomer. The approach of the holiday season makes now an especially appropriate time to discuss the topic. Before you shell out your hard-earned money for a

telescope, ask yourself this question: Am I familiar enough with the night sky to single out the naked-eye planets, as well as major stars and constellations?

If you answered "no," you may want to rethink buying a telescope at this time. A telescope won't do you any good if you can't find your way around the night sky. You can't train your telescope on the Andromeda Galaxy if you can't find the constellation. First, spend time getting acquainted with the major stars and constellations. I recommend a handy little guide called *365 Starry Nights*, by Chet Raymo. Follow Raymo's night-by-night lessons and by next holiday season, you'll be sky-savvy and telescope-ready.

If you answered "yes," you're probably ready for a telescope, so I'll begin by telling you what *not* to get. Do *not* purchase a department store telescope retailing for \$100 or less that promises incredibly high magnification. You'll get inferior optics perched on a rickety mount. And don't go spending a king's ransom on a super-large, high-tech scope. It is better to start with a modest-sized, good-quality telescope priced between \$200 and \$500.

A great telescope for the first-timer is a compact rich-field reflector like Edmund Scientific's Astroscan or Bushnell's Voyager. These compact scopes are durable, quick to set up, and easy to use. Both produce spectacular low-power, wide-field views of the sky but can handle the higher magnifications for viewing the Moon and planets. I used an Astroscan to glimpse the quasar 3C-273, an object located an estimated *two billion* light-years away!

In recent years, a few companies have begun offering "go-to" telescopes. These remote-controlled, computerized instruments allow the user to select a sky object from a menu, press a button, then wait as the scope automatically moves to the target. Sounds neat, eh? Beware: These scopes require careful alignment beforehand, a process made much easier if you know your way around the night sky. If you are technically inclined (translation: you can program a VCR), a go-to scope might be



THE LUNAR ECLIPSE OF NOVEMBER 8 will be a treat even for the naked-eye observer, but don't be shy about obtaining a close-up view with a new telescope. DAVE HOLLAND

for you. Because of the added cost of electronics, a typical go-to telescope will cost more than a standard scope of equal size, but you'll still find good models between \$300 and \$500.

For more ideas, check out the "Super scope buyer's guide" beginning on page 82. This review contains a few scopes that suit the needs of the beginner. Remember, a wisely-chosen telescope, if properly used and cared for, will provide a lifetime of cosmic adventures. Also, keep in mind the view through a telescope doesn't show "everything," and a lot of action "up there" is better viewed with the unaided eye. Speaking of which, November offers two exciting naked-eye shows.

If you live near me (the northeast United States), clouds spoiled May's total lunar eclipse. Fortunately, we all get a second chance the evening of November 8.

A total lunar eclipse occurs when the Full Moon drifts into Earth's shadow. Normally, a Full Moon floods the sky with light and blots out all but bright planets and stars. Things change when a Full Moon is eclipsed. During the early stages of November's eclipse, look for the Pleiades (Seven Sisters), located 12° east (left) of the Moon. You may not see anything, but as the eclipse progresses, this cluster should come into view.

If you follow the astronomical scene, you know the Leonid meteors make headlines each November. This annual meteor display exhibits astonishing increases in activity every 33 years — the most recent increase occurring within the past few years. Indications suggest the shower is returning to its normal quiet state (about a half dozen meteors per hour). But meteor showers can be quite unpredictable. Take a few minutes on the mornings of November 17th and 18th to go outside for a look-see. You may be surprised.

NEXT MONTH: Some binocular tips. Clear skies! ■

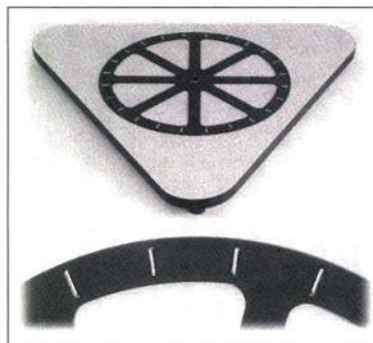
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Michael Turner

No matter if he's teaching a college physics class, chairing high-level NASA committees, or taking a hot bath, you're sure to find this University of Chicago and Fermi Institute cosmologist within the confines of his laboratory. After all, the universe is Michael Turner's lab. ◀ Without Bunsen burners and Erlenmeyer flasks, Turner

probes the vastness of outer space to glimpse the interplay between the fundamental forces binding the cosmos and the particles that characterize it. Meanwhile, he treads so close to the cutting edge of science trying to crack the code of our existence, he actually helps to define it.

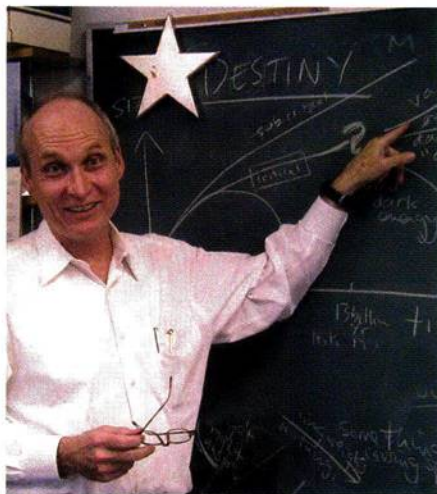
How does the modern era of "precision cosmology" differ from previous ones?

Few fields in their early discovery phases are characterized by precision. For decades, cosmology has been plagued by an image of imprecision and general flakiness: from Rubin Landau's "cosmologists are often in error, but never in doubt" to the oft stated "in cosmology the errors are in exponent."

Since 1992, when the COBE satellite discovered the tiny temperature variations across the sky and measured the universe's background temperature to 2.725 kelvin, cosmologists have been making reliable measurements with small, believable error bars. Even the Hubble constant — measuring the rate of the universe's expansion — has been wrestled into submission and measured to within 10 percent. The precision we now see in cosmology is a sign of maturity resulting from better instruments and a better understanding of the universe.

What about the challenges posed by an infinite laboratory?

Cosmologists will never be able to set up and carry out controlled experiments. But that doesn't mean we can't make convinc-



MICHAEL TURNER studies the "big picture." From his office at the University of Chicago to the outer reaches of the universe, Turner seeks to understand the destiny of it all.
U. OF CHICAGO/JENNIFER SMITH/DANA NASSAU

ing cases for our ideas. Take, for example, that the universe began from quark soup. We can observe the Cosmic Microwave Background (CMB), which reveals when matter was hot, ionized, and smoothly distributed. We can measure the abundances of the light elements and reason that they were produced by nuclear reactions when the universe was seconds old. And, we can carry out experiments proving very dense matter exists as a quark/gluon plasma.

Could cosmology collapse if we discover our place in the universe to be atypical?

That will take some doing. Evidence to support the Copernican Principle, namely

the idea that we live in a typical place, is at an all-time high.

But if, as inflation theory predicts, the universe is comprised of infinite, disconnected, inflationary bubbles, then the local laws of physics could differ dramatically from bubble to bubble, and ours could be the rare bubble hospitable to life. If this "multiverse" theory is correct — currently we don't know how to test it — we *will* see a paradigm shift as dramatic as the Copernican revolution that removed Earth from the center of the universe.

Without universal paradigm shifts, how can we ensure that our curiosity continues to breed knowledge and understanding?

With more bold ideas and more powerful instruments — the same stuff powering explosive cosmological advances today.

Today's big ideas all involve intimate connections between the elementary particles and the biggest things in the universe — dark matter made of a new type of particle, cosmic acceleration due to a new form of "dark energy," and quantum fluctuations during inflation seeding all the structure seen in the universe today.

Technological advances have been no less impressive — 100 megapixel (soon gigapixel) CCD cameras, studies across the electromagnetic spectrum, and accelerators that replicate conditions 10 picoseconds after the Big Bang.

On both accounts, the future is bright with superstrings, extra dimensions, gravity-wave detectors, and the James Webb Space Telescope, to mention a few.

What's the greatest cosmological achievement of all time?

My next paper! Seriously . . . we are in a period of discovery without precedent. The opportunities for truly seminal breakthroughs are great. Stay tuned. ■



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Blimey! The lads at Meade have done it again. All of their **ETX telescopes** now

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Be on the lookout!
Two years in the making, **SBIG's new research grade cameras** are nearing the horizon and are perfect for



seaworthy astrophotographers. Never before have there been easier to use CCDs of this size and resolution.



Time and tide wait for no man. Through September 30th you can snag a **free 3-6mm Nagler Zoom** with ye' purchase of an NP 101 from OPT. Great for astrophotography, it also be a handsome landlubber telescope.



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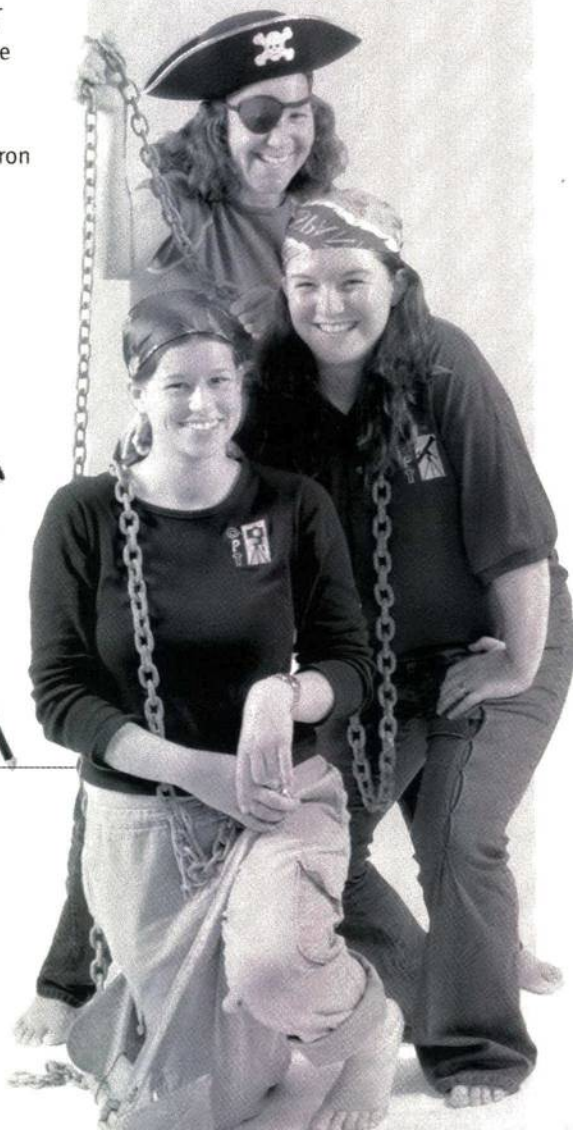


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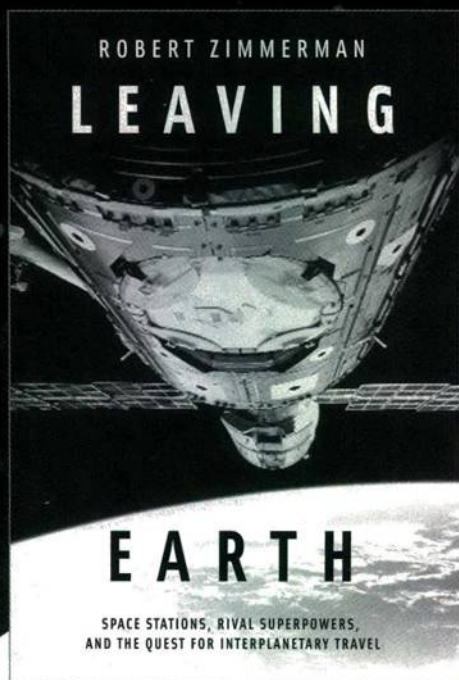
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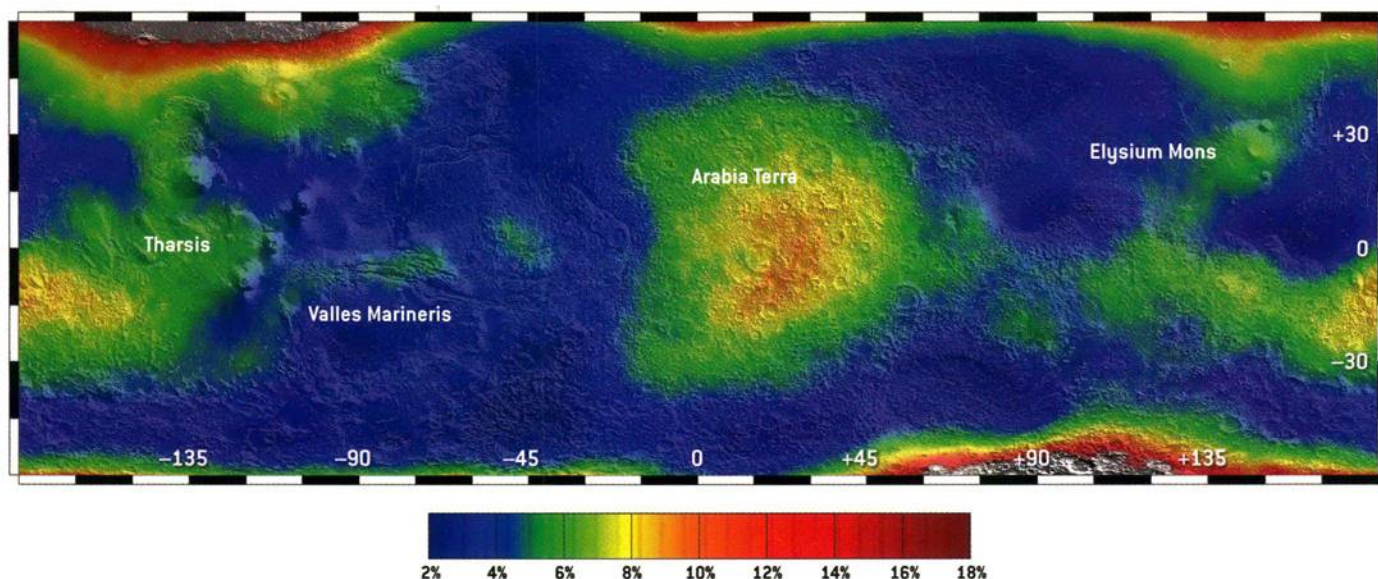
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news II

Read all about it: A newly discovered kind of avalanche on Mars, an exoplanet's magnetosphere, comet-discovery awards, archaeology of the Milky Way, and sailing on a sunbeam.



A WET MARS EMERGES in new results from instruments aboard the Mars Odyssey spacecraft. Based on hydrogen detected in the ground, this map shows the percentage of water contained in the soil. In the polar regions, the amount approaches or reaches 100 percent, while the quantity varies elsewhere. LANL

MARS GEOLOGY

New maps show water near surface of Mars

New maps of Mars based on data from NASA's Mars Odyssey spacecraft show that hydrogen lies close to the planet's surface — perhaps only a few inches deep in many areas. Scientists think hydrogen indicates the presence of water ice.

"A lane of hydrogen-rich material follows the western slope of Tharsis, which has the biggest volcanoes in the solar system," says Los Alamos National Laboratory scientist Bill Feldman, leader of the team that made the measurements. "A maximum reading sits right on the volcano Elysium Mons, another lies in Arabia Terra, and a third, smaller lane passes across the deep canyon Valles Marineris."

From about $\pm 55^\circ$ latitude to the poles, the martian soil contains enough water to make up half its mass — a pound of scooped-up soil would release half a pound of water when warmed. Closer to the equator, the soil contains less water: 2 to 10 percent by mass.

Scientists have two theories for how water may have lodged in the ground. One says the ice caps block geothermal heat, melting at their bottom layer to feed a water table. The other theory looks to periodic changes in Mars's orbit, which could have caused the ice caps to evaporate and deposit water globally from a thicker and wetter atmosphere. — ROBERT BURNHAM

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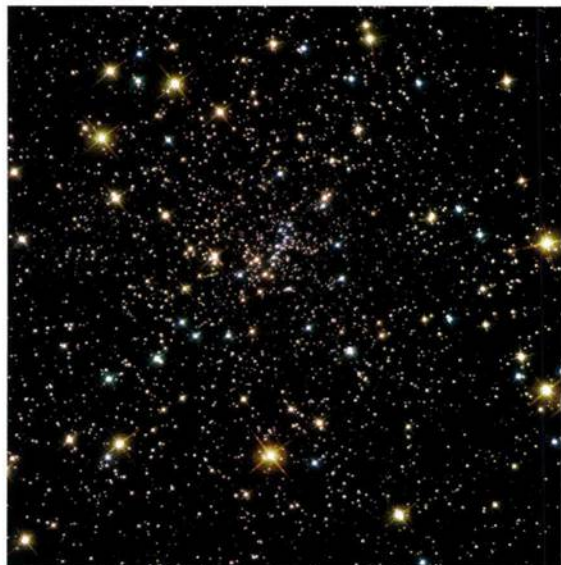
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HUBBLE HERITAGE IMAGE

It's crowded in here



LOOKING DEEP into globular cluster NGC 6397, the Hubble Space Telescope probed in the core of the cluster for stars showing the effects of the crowding. NASA/STScI

New results from the Hubble Space Telescope and the Chandra X-ray Observatory open a window into the rough environment at the heart of dense globular clusters. Globulars pack as many as a million stars into a ball roughly 100 light-years across. Encounters between stars occur every few hundred years, with collisions typically every few million years.

The Hubble image, combining photos taken in 1997, 1999, and 2001, shows NGC 6397 in Ara the Altar. Several teams of astronomers used the images to identify cataclysmic variable stars. These pair a normal star with a white dwarf that is attracting gas from the normal star. When the gas crashes onto the white dwarf, it explodes, briefly brightening the star system.

Observations using Chandra suggest that close encounters between neutron stars or massive white dwarfs and normal stars can form x-ray-emitting binary pairs. X rays are emitted as material falls onto a neutron star or a massive white dwarf and explodes more violently than with a cataclysmic variable.

A team led by David Pooley (MIT) tallied the x-ray binaries in 12 globulars. The team saw that the denser the cluster, the more x-ray binaries it has.

"We found the number of x-ray binaries closely correlates with the rate of encounters between stars," explains Pooley. "We concluded that binaries form as a result of these encounters." — VANESSA THOMAS AND R. B.

SOLAR SYSTEM

Pluto's atmosphere

Contrary to expectations, the atmosphere of Pluto is expanding in size as the planet moves farther from the Sun.

A team of scientists led by James Elliot (MIT) monitored the passage of a star behind Pluto and discovered the planet's



PLUTO'S ATMOSPHERE will be a major target in 2015 for the New Horizons probe. JHUAPL/SWRI

atmosphere is deeper and warmer than 14 years ago, when Pluto was closest to the Sun.

Elliot explains the increase by a lag effect also seen on terrestrial afternoons. "In terms of Pluto's orbit," he says, "right now it's like 1:15 P.M." — R. B.

EXTRAGALACTIC ASTRONOMY

Galaxies without stars?

Astronomers at the Australian National University (ANU) have found 20 objects that each contain nearly a billion solar masses of hydrogen but almost no stars.

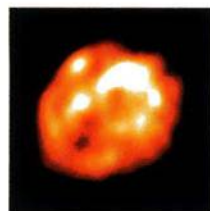
"When you look at the gas, the radio signal just booms in," says Brad Warren (ANU). "But stars? All you see is a smudge."

The new galaxies were found by the HI Parkes All Sky Survey. Each is a vast, rotating disk of hydrogen gas, about 35,000 light-years across, with a small number of stars in its center.

The objects lie 12 to 65 million light-years away.

The astronomers suspect these objects have not formed stars yet because many are isolated. Making stars, they think, may require interactions with neighbors to stir up a galaxy's gas.

— ANNIE HUGHES



A LOT OF GAS but few stars makes a galaxy "empty." BRAD WARREN/ANU

EXTRASOLAR PLANETS

Exoplanet magnetosphere found

Researchers at the University of British Columbia (UBC) and the Harvard-Smithsonian Center for Astrophysics (CfA) have reported the first detection of an exoplanet's magnetosphere.

They found periodic enhancements in calcium emission from the star HD 179949, which is hotter and more massive than the Sun. This star was targeted because those of its spectral type (F8) have magnetic fields much stronger than the Sun's. The observed emission changes coincided with the orbital period of the star's Jupiter-sized planet.

The researchers suggest that charged particles from the planet

travel down magnetic field lines to collide with the star's corona, heating it. As the planet passes in front of the star, the active region crosses our line of sight, producing increased stellar emission.

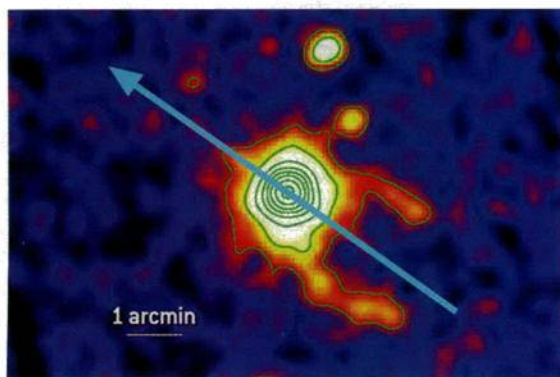
The research team ruled out a gravitational origin for the enhanced emission because tidal effects would have raised a bulge on two sides of the star, creating variations with half the planet's period. They also eliminated the possibility of a bright feature on the star's surface. Such a feature would stand out clearly because the star's rotation period lasts about three times longer than the planet's orbital period. — A. H.



HIGH-ENERGY ASTROPHYSICS

In the wake of Geminga

Puzzling astronomers for more than thirty years, a neutron star named Geminga has revealed another twist to its bizarre story. Using the European Space Agency's x-ray observatory, XMM-Newton, researchers found a unique pair of colossal x-ray tails trailing about a third of a light-year behind the dead star.



LIKE TWO EXTENDED FINGERS, tails of energetic electrons and positrons lag behind Geminga, a fast-moving, nearby pulsar. ESA

A team led by astronomer Patrizia Caraveo of the Istituto di Astrofisica Spaziale e Fisica Cosmica in Milan, Italy, believes a wave of charged electrons and positrons escaping the intense magnetic field surrounding Geminga formed the diffuse tails.

"It's astonishing that such energetic electrons succeeded in escaping to create these tails," says Caraveo.

The astronomers' calculations show that as Geminga hurtles through space at 75 miles (120 kilometers) per second, its magnetic field is squashed into a "bow shock" in front of the star, while these spectacular x-ray tails stretch out at the back like a wake behind a ship. The geometry of the tails shows the star is moving almost directly across our line of sight.

Geminga lies at a distance of 500 light-years in the constellation Gemini and is one of the closest pulsars to Earth. It rotates like a lighthouse once every quarter second. Believed to have formed in a supernova 350,000 years ago, this city-sized, hot ball of neutrons is unlike most young, fast-spinning pulsars in that it maintains radio silence.

Caraveo and her colleagues think scores of currently unidentified gamma-ray sources may be "radio-quiet" pulsars like Geminga. Astronomers already have found about a dozen of these strange stellar beasts — but only Geminga sports a pair of tails.

— ANDREW FAZEKAS

EXTRASOLAR PLANETS

Metals make planets

A survey of 754 nearby Sun-like stars has shown that stars with a high content of elements heavier than helium — "metals" — are more likely to form planets.

Debra Fischer (UC-Berkeley) explains, "Astronomers note that only 5 percent of all stars have planets. But we now know that of the stars abundant in heavy metals, 20 percent have planets. That's stunning."

Elements heavier than helium are created by nuclear reactions in stars and ejected into the interstellar medium through supernova explosions. Metals were rare in the early Milky Way, but each successive stellar generation has more heavy elements as interstellar gas is recycled. This means new stars have better chances of making planets because heavier elements coalesce more easily, allowing dust, rocks, and planetesimals to form. — A. H.

ASTROBIOLOGY

Finding life with robots isn't easy

Convincing scientists that instruments have found life on another planet may prove somewhat difficult.

Astrobiology field tests using a rover in Chile's Atacama Desert uncovered a problem with robotic probes. Planetary scientists and microbiologists from NASA and Carnegie Mellon University saw lichens and evidence of bacteria colonies. But their instruments could not provide a definitive confirmation of life.



FINDING LIFE using a robot takes sophisticated tests. CARNEGIE MELLON UNIVERSITY

The researchers are now planning new tests using different techniques.

They will spray soil samples with four dyes that fluoresce only when they are bound to biomolecules — nucleic acids, proteins, lipids, and carbohydrates.

If all four dyes light up in a single sample, that should convince even the toughest skeptics.

— TIM PALUCKA

MARS SCOUT 2007

Phoenix: to Mars's polar regions

NASA has chosen the University of Arizona's Phoenix lander spacecraft as the sole Mars Scout mission for 2007. Phoenix will



THE ROBOT ARM of Phoenix should find water or ice less than a yard below the surface of Mars. NASA/LPL/UNIV. OF ARIZONA

launch in August 2007 and touch down on Mars (around 65° north and 130° west) in May 2008. Unlike the two MER landers due to arrive in January 2004, however, Phoenix is not a rover; it will stay in place where it lands.

Phoenix's instruments are optimized to seek and analyze subsurface water or ice. They also will look for organic traces in the soil and possible biohabitats.

The payload includes a descent imager to characterize the landing site's geological context, a stereo imager for high-resolution mapping of the surroundings, a gas analyzer, and an environmental survey package.

Most of the instruments are tested designs from the never-flown Mars Surveyor 2001 probe and the Mars Polar Lander that crashed in 1999. — R. B.

MARTIAN GALLERY

Catchall crater



LOW SPOTS COLLECT DEBRIS, and low spots that water flows through collect even more. This 20-mile [30-km] crater forms part of a valley network in Mars's southern highlands. Material in the crater records many episodes of deposition, landslides, and impact cratering. NASA/JPL/ASU/THEMIS VISUAL IMAGE 20030730A

AMATEUR ASTRONOMERS

Comet awards

The Smithsonian Astrophysical Observatory recently presented the 2003 Edgar Wilson Award for discoveries of comets by amateurs to five people. Each recipient received a plaque and a cash prize of about \$3,400.

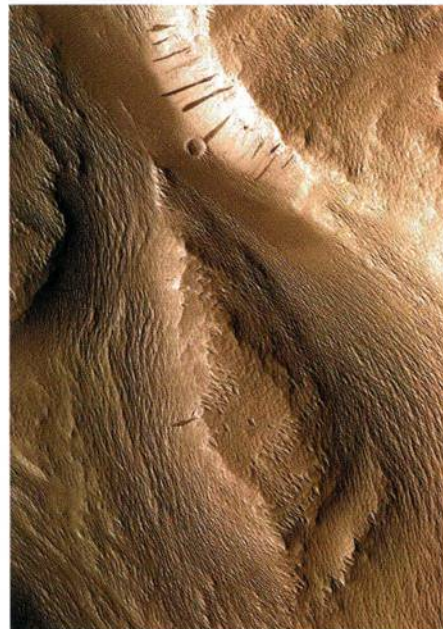
Tetuo Kudo and Shigehisa Fujikawa, both of Japan, made independent visual discoveries of comet C/2002 X5. Kudo is an astrophotographer who found the comet while waiting to finish an exposure. Fujikawa, a six-time comet discoverer, made his first discovery in 1969.

Comet C/2002 O4, visually detected by Sebastian Hoenig, was the first discovery by a German since 1946.

Communicating via the Internet, Charles Juels and Paulo Holvorcem co-discovered comet C/2002 Y1 from their homes in the United States and Brazil, respectively.

Despite growing competition from professional programs, amateur observers still make contributions. Indeed, 15 of the last 25 Wilson awards went to observers who made visual discoveries. — LAURA BAIRD

MARS PHOTOJOURNAL



TWO KINDS OF EROSION left traces in Labou Vallis on Mars. Water spilling out of the large Mangala Valles system carved Labou as a 170-mile [270-km] valley across cratered terrain in Terra Sirenum. Later, loose material was deposited on the landscape. Then the wind, blowing over and through the valley, cut a smaller-scale pattern into the material. NASA/JPL/MSSS/IMAGE M07-03611

MARS GEOLOGY

A new type of martian landslide

Caltech researchers poring over images from the Mars Global Surveyor have found more than 560 examples of a new type of geological feature on Mars.

It is a landslide that leaves a large, shallow, triangular scar with straight sides and a rampart of debris at the foot. These landslides differ in shape, texture, and bright-

ness from the common dark streaks, which are thought to be dust avalanches — and they also differ from the gullies, believed to have been eroded by meltwater.

Scientists Marguerite Gerstell, Oded Aharonson, and Norbert Schorghofer note that these scars of massive avalanches, 13 to 33 feet thick, have been found mostly in areas of past volcanic activity. Many lie on the aureole deposits northwest of Olympus Mons.

They hypothesize that the slides occur in a loosely consolidated surface layer, perhaps volcanic debris that settled from the air. This layer could slide on a more compacted, lower deposit. — R. B.



TRIANGULAR SCARS mark the sites of large, dry avalanches — a newly discovered landform on Mars. NASA/JPL/MSSS

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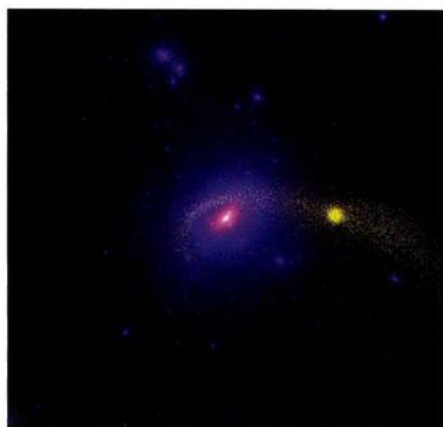
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MILKY WAY GALAXY

Galaxy history

A team of Australian astronomers has embarked on an ambitious research project to unravel the Milky Way — literally.

Dubbed “galactic archaeology,” the project will trace stars in our galaxy back to their birthplaces. “We seek signatures or fossils from the epoch of galaxy formation,” explains Joss Hawthorn of the Anglo-Australian Observatory.



BY DEVOURING DWARF GALAXIES, the Milky Way has absorbed many stars. Astronomers seek to unravel our galaxy's history by tracing these stars' velocities and compositions. SWINBURNE UNIV.

Stars form when a cloud of dusty gas collapses under gravity and creates a cluster of a few hundred to several thousand stars. Stars from the same cluster have identical chemical compositions and, at least initially, move through the galaxy on similar orbits. Astronomers suspect, however, that many stars in our galaxy are interlopers from satellite galaxies engulfed by the Milky Way.

By analyzing chemical abundances and velocities for over 50 million stars, the team hopes to determine where stars originated. The result will be a star-by-star reconstruction of the galaxy's formation.

Astronomers often study where galaxies came from by looking back to the early universe. But, says Hawthorn, “these objects are extremely faint, and some secrets may be discovered by observing stars in our own galaxy.” — A. H.

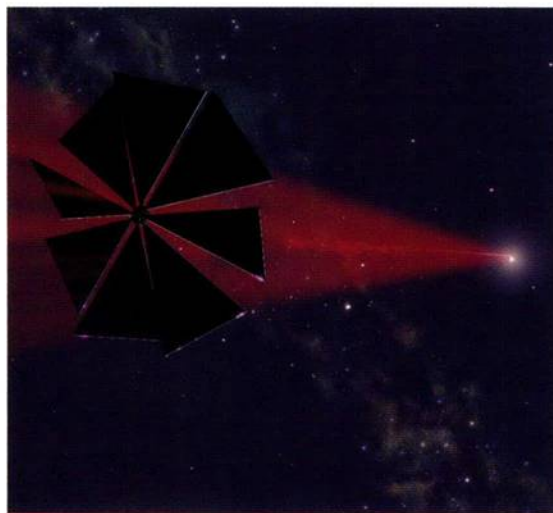
Sailing on a sunbeam — at last?

After decades of dreaming about “solar sailing” — using sunlight to push a space vehicle — the first orbital test is drawing near. The road to solar sailing has been difficult, and experience warns that even greater difficulties lie ahead, but the test will be a big step toward making this technology work.

Funded privately through The Planetary Society in California, a small package called Cosmos-1 will be shot into orbit from the northern coast of Russia aboard a Volna rocket. The Volna is a converted Soviet submarine-launched ICBM.

As with any bargain-basement hardware, the Volna launch system has proven problematic on past attempts. On one occasion, an upper stage misfired. Another time, the payload separation system failed. After that was fixed, the payload fell off during flight, perhaps due to another separation system error. Tests indicate that engineers have eliminated the flaws now.

The 220-lb (100-kg) payload is being fabricated by a team in Moscow that used to build interplanetary space probes for the Soviet Union. It will deploy 50-foot (15-meter)-long inflatable spars holding eight triangular sails that can be



RIDING A LASER BEAM from Earth, an interstellar version of Cosmos-1 sets sail. Harnessing the pressure of light is a long-overlooked technology in spaceflight. MICHAEL CARROLL/PLANETARY SOCIETY

rotated to control the angle of sunlight falling on them. The force of solar photons hitting the sails creates enough pressure to push the vehicle forward.

People sometimes think, erroneously, that the solar wind does the pushing. In fact, the solar wind, a flow of ions ejected from the Sun, is much weaker than photon pressure. The confusion probably arises because the technology is called “solar sailing,” and sailing naturally calls for wind.

There's no question that solar sailing works. Photon pressure is taken into account with all spacecraft, and interplanetary missions would arrive far off course if it were ignored. When a solar sail spreads its wings, the effect will be quite spectacular.

The plan is for the Volna rocket to put this payload into polar orbit about 500 miles (800 km) up, high enough so air drag won't overwhelm the pressure from the sunlight. Once aloft, the spacecraft's orbit will be raised gradually.

Spacecraft using more advanced solar sails could carry “slow-boat” science missions — or even supplies for astronauts — on interplanetary trajectories. Such spacecraft would indeed be “light sails” in several senses of the phrase, as a space theoretician once suggested.

For the foreseeable future, however, NASA has no plans for any such missions. Thus, it has fallen to private funding by advocates to pioneer this unlimited, new technology.

— JAMES OBERG

NEW Celestron StarBright XLT High Performance Optical Coatings Outperform The Competitor's UHTC.

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One of the most important factors in the evaluation of a Schmidt-Cassegrain telescope's optical system performance is its transmission — the percentage of incoming light that reaches the focal plane. The design of the XLT System accomplishes two crucial objectives: Develop a coating system that is optimized for visual use and for CCD/Photographic imaging.

Celestron StarBright XLT: The Bottom Line.

- 11% brighter than UHTC across the spectrum from 400nm to 750nm. (See Fig.#1)
- 11% more photons will be detected with a CCD camera using StarBright XLT coating system compared to UHTC coatings (See Fig.#2)
- 6% brighter than UHTC to the dark-adapted eye (See Fig.#3)
- 16% brighter than our standard StarBright coating across the spectrum from 400nm to 750nm.

System Transmission At Specific Wavelengths — Celestron StarBright XLT vs UHTC

	Wavelength (nm)	StarBright XLT	UHTC Measured	Percent Improvement
H-beta	486	87.5	83.0	5%
Helium II and O ₃	496	88.0	84.0	5%
O ₃	501	88.0	84.3	5%
Center of dark adapted vision	510	88.7	84.8	5%
Helium I	588	88.0	81.6	8%
N ₂	655	84.0	73.8	14%
N ₂ and H-alpha	658	84.0	73.0	15%
Sulfur II	673	83.0	72.0	15%

System Transmission for StarBright XLT and UHTC

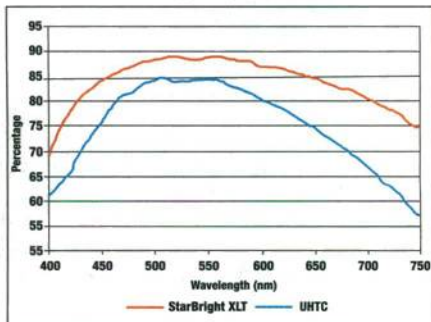


Fig #1: This is a plot of measured system transmission for Celestron's StarBright XLT and UHTC coatings. The StarBright XLT coating has an overall average system transmission of 83.5% compared to UHTC at 75.1%. System transmission is determined by taking the measured value of the reflectance of the primary, times the reflectance of the secondary, times the transmission of the corrector lens.*

CCD Imaging — It's All In The Photons

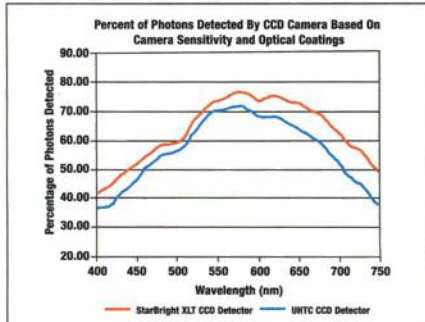


Fig #2: StarBright XLT is not only optimized for visual use, it is also optimized for imaging. This plot takes into account the sensitivity of a popular CCD chip (KAK-3200 used in SBIG's ST10ME) in conjunction with the system transmission based on the optical coatings. Our measurements indicate that the CCD chip will detect 11% more photons with Celestron's StarBright XLT than UHTC.*

The StarBright XLT System — What makes it different makes it better. — There are three major components that make up our StarBright XLT high transmission optical system design:

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2. **Multi-layer anti-reflective coatings** — Made from precise layers of MgF₂ (magnesium fluoride), and HfO₂ (hafnium oxide). A rare element costing nearly

\$2000 per kilogram, hafnium gives us a wider band pass than titanium, used in UHTC coatings.

3. **High transmission water white glass** — Celestron Schmidt-Cassegrain optical systems with optional StarBright XLT coatings use water white glass instead of soda lime glass for the corrector lens. **Water white glass transmits about 90.5% without anti-reflective coatings.** That is 3.5% better transmission than uncoated soda lime glass. **When water white glass is used in conjunction with StarBright XLT's anti-reflective coatings, the average transmission reaches 97.4% — an 8% improvement!**

Coming Out of the Dark — StarBright XLT Performance Where It Counts

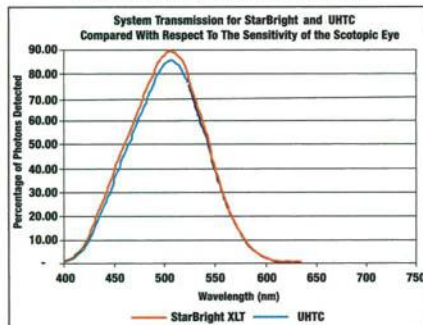


Fig #3: The scotopic, dark adapted eye is most sensitive at about 510nm. The dark-adapted eye has nearly zero sensitivity below 400nm and above 650nm. This plot compares StarBright XLT and our measurement of UHTC taking into account the sensitivity of the human eye. The result is that StarBright XLT is a 6% improvement over UHTC for visual observing.*

UHTC Coatings Don't Measure Up To StarBright XLT

In order to determine how our newly designed XLT performs compared to the competition, we tested several optical systems with UHTC coatings. All measurements have been conducted with spectrophotometers measuring light transmission of coated correctors and reflectance of coated mirrors. This allows us to compare the transmission of our correctors and the reflectance of our mirrors against those of the competition. To ensure the integrity, accuracy, and reliability of these test results, they have been independently verified. A detailed description of our testing process can be found on our website: www.celestron.com/starbrightxlt.*

***Percent differences are calculated by taking the comparison data percentage divided by the baseline data. Example: Measured average system transmission for UHTC is 75.1%. XLT average system transmission is 83.5%. 83.5% divided by 75.1% = 1.11 or 11% improvement. Measurement results are rounded to the nearest whole percentage.**

StarBright XLT Pricing

All 8" Schmidt-Cassegrain Products.....	\$125
All 9.25" Schmidt-Cassegrain Products.....	\$175
All 11" Schmidt-Cassegrain Products.....	\$225
All 14" Schmidt-Cassegrain Products.....	\$275



NEW 2003 PRODUCT GUIDE

To request a copy of Celestron's new 2003 Product Guide, contact us at (310) 328-9560.



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For more information about StarBright XLT visit: www.celestron.com/starbrightxlt

To design the perfect telescope family for the beginner or advanced user, you have to think BIG.

CG-RGT
[#11046]

C8-S/C8-SGT/C9 1/4-S/C9 1/4-SGT
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The new Advanced Series and Advanced Series **Computerized GoTo** telescopes have been designed to offer the novice or more advanced user a selection of models with the **features, quality and value** that serious amateurs can appreciate. These scopes come on **NEW heavy-duty German Equatorial mounts** with **NEW ultra-sturdy**

2" stainless steel legs and center brace and accessory tray for



Auxiliary ports for Hand Control, Dec Motor and AutoGuide.

superior stability, rigidity and vibration dampening. The Advanced Series comes in a choice of refractor, reflector and Schmidt-Cassegrain models. The refractor models range from a 4" to an impressive 6" aperture. For even more light gathering power there are 6", 8" and a **NEW 10" Newtonian reflector**. There are also 5", 8" and 9 1/4" Schmidt-Cassegrain optical designs that feature Celestron's precision **matched and hand-figured** optical systems.

CG-5 Mount — Precision engineered for stability.

Additional Specifications — Computerized Models

Hand Control	Double line, 16 character Crystal Display, 19 fiber optic backlit LED buttons
Motor: Type	DC Servo motors with encoders, both axes
Max Slew Speed	4°/second
Software Precision	24bit, 0.06 arcsec calculation
Hand Control Ports	RS-232 communication port on hand control
Motor Ports	Aux Port, AutoGuide Ports
Tracking Rates	Sidereal, Solar and Lunar
Tracking Modes	EQ North & EQ South
Alignment Procedures	AutoAlign, 2-Star Alignment, Quick Align
Database	40,000+ objects, 400 user defined programmable objects

Our new German Equatorial mount has precision worm gears on both axes for extremely smooth tracking and slewing. The CG-5 uses large shaft and bearings and substantial base castings for additional stability. The key element that makes this system the most stable in its class is the **NEW heavy-duty tripod** with **larger and more substantial legs** that offer excellent damping characteristics for more

stable views. The CG-5 also has a convenient **latitude scale** for easier alignment and an **optional polar finder scope** for the ultimate in precision alignments.

GoTo convenience and GPS compatibility for precision accuracy.

We are proud to offer the GT versions of the Advanced Series on a computerized **GoTo** version of Celestron's sturdy CG-5 mount. Couple this solid mount with the included **NexStar computer control system** and utilize many of the same features as Celestron's most advanced GoTo telescopes like an **Autoguider port** for long exposure deep sky astro-photography.

GoTo models are also upgradeable to GPS with the optional **CN16 GPS Accessory (#93963)**. It allows your telescope to pinpoint your position on the Earth, the date and time, and making the alignment process faster and easier than ever before! These GoTo versions of the Advanced Series also come loaded with new software features and **over 40,000 database objects**. Capable of holding over 35 lbs of payload and slewing at 4° per second, you will be able to instantly point to any of the celestial objects in the database.

C9 1/4-SGT
[#11046]

C10-NGT
[#11048]

Specifications — All Advanced Series Telescopes

21016 C4-R	11071/11072 C5-S	31056 C6-N	21019/21020 C6-R	11025/11024 C8-S	31061/31062 C8-N	11045/11046 C9 1/4-S	11047/11048 C10-N
Optical Design	102mm (4.0") refractor	127mm (5") Schmidt-Cassegrain	150mm (6.0") reflector	150mm (6.0") refractor	203mm (8") Schmidt-Cassegrain	200mm (8.0") reflector	254mm (10") reflector
Focal Length	1000mm f/10	1250mm f/10	750mm f/5	1200mm f/8	2032mm f/10	1000mm f/5	1200mm f/4.7
Finder Scope	6x30	6x30	6x30	9x50	6x30	9x50	9x50
Mount	CG-4 Equatorial	CG-5 Equatorial	CG-4 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial	CG-5 Equatorial
Eye Piece	1-1/4" - 20mm (50x)	1-1/4" - 25mm (50x)	1-1/4" - 20mm (38x)	1-1/4" - 20mm (60x)	1-1/4" - 25mm (81x)	1-1/4" - 20mm (50x)	1-1/4" - 20mm (60x)
Star Diagonal	1-1/4"	1-1/4"	n/a	1-1/4"	1-1/4"	n/a	n/a
Accessory tray	yes	yes	yes	yes	yes	yes	yes
Tripod	Aluminum	2" Stainless Steel	Aluminum	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel	2" Stainless Steel
CD ROM	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1	The Sky Level 1

PRICING: C10-NGT (#11048): \$1,149 + \$95 S&H; C10-N (#11047): \$849 + \$75 S&H; C9 1/4-SGT (#11046): \$1,699 + \$105 S&H; C9 1/4-S (#11045): \$1,399 + \$85 S&H; C8-SGT (#11026): \$1,299 + \$75 S&H; C8-S (#11025): \$999 + \$85 S&H; C8-NGT (#31062): \$949 + \$85 S&H; C8-N (#31061): \$649 + \$65 S&H; C6-RGT (#21020): \$999 + \$95 S&H; C6-R (#21020): \$799 + \$75 S&H; C6-N (#31056): \$399 + \$50 S&H; C5-SGT (#11072): \$1,099 + \$75 S&H; C5-S (#11071): \$849 + \$65 S&H; C4-R (#21016): \$399 + \$40 S&H

*Prices shown are U.S. mail order.

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NexStar[®] 5i and 8i. Complete, Affordable Computerized GoTo Systems.

Celestron NexStar 5i and NexStar 8i. Complete systems that include a computerized hand control and tripod!

Celestron's affordable NexStar 5i and NexStar 8i are exciting additions to our renowned NexStar family of computerized GoTo GPS telescopes that includes the NexStar 8 GPS, NexStar 9.25 GPS, and 11 GPS. NexStar 5i and NexStar 8i take the best of our coveted NexStar 5 and 8 to the next level of performance and operating features. The 5i and 8i include *all* of Celestron's newest hardware and software enhancements in an affordable and expandable system. Most important, the 5i and 8i will **automatically locate the alignment stars** when used with the **optional CN16 GPS Accessory (#93963)**, and you can put the power of our newest software features and expanded object database to work with the **included computerized hand control**.

5i and 8i Hardware Features:

Two Ports Conveniently Located On The Drive Base:

- **AutoGuide Port** — Easy connection of AutoGuider for astrophotography.
- **Auxiliary Port** — Use for smart accessories like our **optional CN16GPS Accessory**.

Computerized Hand Control With New Software Features.

With the computerized hand control, you get a myriad of important new functions. This hand control is the next evolution of the most user-friendly, intuitive hand control in the industry.

Computerized Hand Control Features:

- **GPS Align Compatible (with optional CN16 GPS Accessory)** — Plug the optional CN16 GPS accessory into the auxiliary port and the telescope automatically aligns with no data input necessary.
- **Auto North and Level Compatible (with optional CN16 GPS Accessory)** — Automatically finds north and level with more precision than can be done by hand, getting you closer to your alignment stars.
- **Hibernate** — This power saving feature lets you power down the telescope without losing your alignment (input time if CN16 GPS accessory is not attached). Great for finding planets in the daytime after aligning at night or observing day after day without having to re-align.
- **Database Filter Limits** — User-defined so that only objects visible above the horizon are displayed on the hand control.
- **Wedge Align Algorithm** — Automatically aligns the telescope to the celestial pole.

Essential when you are performing polar alignment on an Equatorial wedge.

- **Quick Align** — An easy way to get an Alt/Az telescope tracking without actually aligning on two stars.
- **40,000 Object Database** — A newly enlarged and expanded programmable user database.
- **User-Defined Slew Limits** — Prevents the telescope from slewing beyond the user-defined horizon.

NexStar Software. Now Our Beauties Come With More Brains.

The beauty of Celestron's NexStar GPS telescopes has always been their unique appearance characterized by their patented design, engineering innovations like patented AutoAlign, user-friendly intuitive software, and solid aluminum construction. We've made them even more attractive by upgrading the software with additional new features that are **included with all Celestron NexStar GPS telescopes including our 5i and 8i**.

Software Features:

- **Compass Calibration** — Allows you to point to true north more accurately, by compensating for magnetic north offset and local anomalies.
- **Polar Alignment Routine** — Facilitates polar alignment for CCD imaging or conventional 35mm astrophotography.
- **EQ AutoAlign** — Now the patented AutoAlign is available even when the telescope is mounted on a wedge.
- **Database Filter Limits** — Now available in Equatorial mode as well as Alt/Az.

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NexStar 5i shown with included Computerized Hand Control and Tripod. Cameras and accessories for astrophotography are optional.

NexStar[®] 5i
\$999*
+ \$50 Shipping & Handling



NexStar 8i shown with included Computerized Hand Control and Tripod. 1.25" Ultima Ocular, and CN16 GPS Accessory are optional.

Optional CN16 GPS Accessory



CN16GPS Accessory — #93963 Mounts to both the NexStar 5i and 8i. Converts the telescope to GPS align for automatic alignment without manually entering any data. — \$199

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Order out of CHAOS

Murder, mayhem, and cannibalism make the Local Group a treacherous place for small galaxies — and a perfect microcosm of the universe as a whole. /// BY RAY VILLARD

Our Local Group of galaxies lies on a side street 50 million light-years from the great intersection of two dark matter filaments that created the magnificent Virgo Cluster of about 2,000 galaxies. To alien astronomers living in the Virgo Cluster, our little galactic neighborhood would appear as two smudges of light: our own Milky Way Galaxy and the Andromeda Galaxy (M31). Together, they might be dismissed as a “binary galaxy” on some extraterrestrial’s star chart. Only with extraordinarily powerful telescopes would Virgo astronomers pluck out the nearly three dozen small dwarf galaxies.

The innocuous name *Local Group* belies the fact that our neighborhood is more like a rough and tumble town in the Wild West. Murder, mayhem, missing bodies — even cannibalism — stalk the streets. In reality, we are seeing order emerge out of the

chaos of energy and matter that followed our universe’s birth; the Local Group is a microcosm of the rowdy cosmos at large.

Merely 6 million light-years across, the Local Group “is the universe in a nutshell,”



according to Mario Livio of the Space Telescope Science Institute in Baltimore, Maryland. But more importantly, in an expanding and accelerating universe, the Local Group provides our only opportunity to decode the origin, structure, and evolution of galaxies.

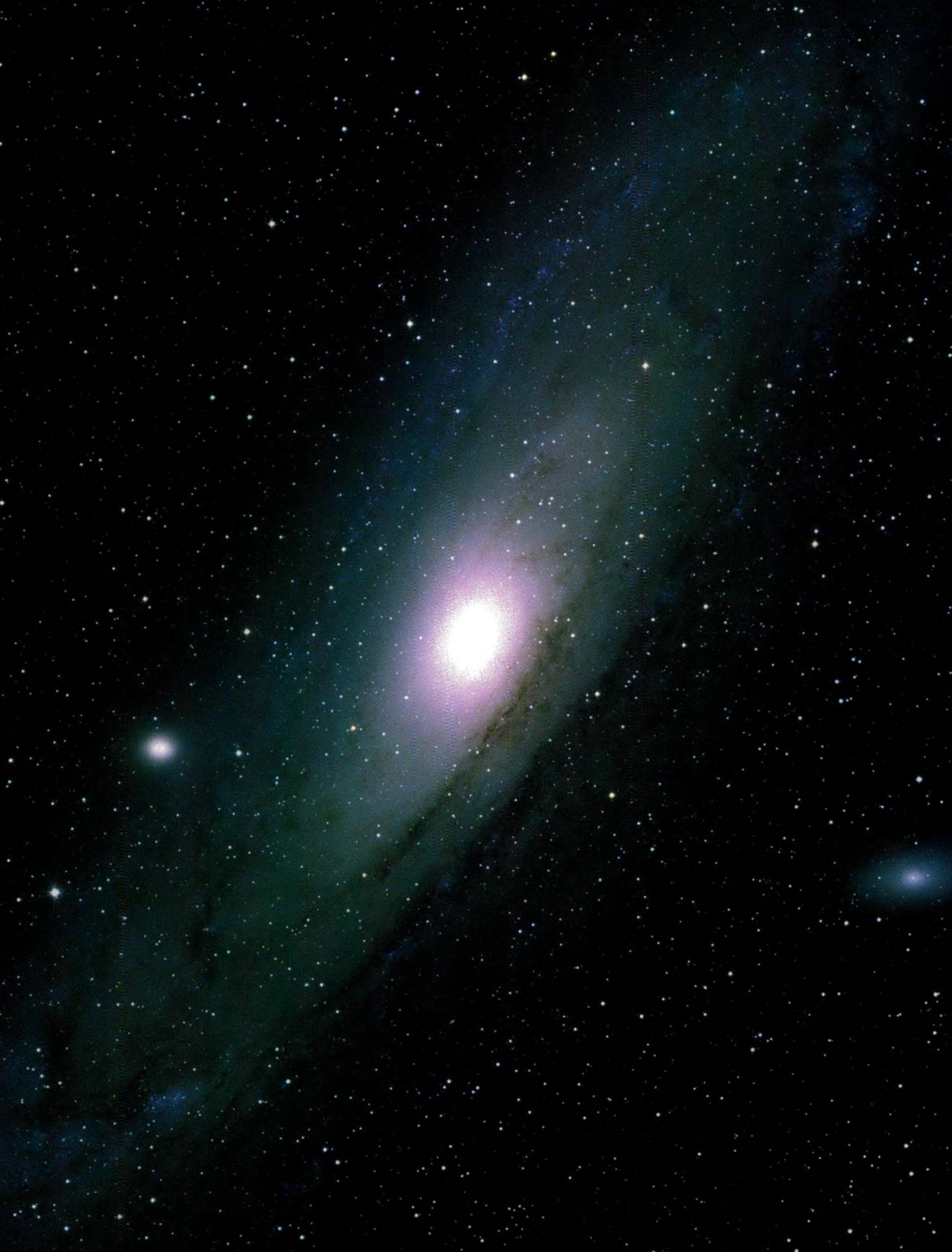
New eyes on the Local Group

The road to discovering the Local Group started eighty years ago. In 1923, American astronomer Edwin Hubble used the 100-inch Hooker Telescope atop Mount Wilson in Southern California to find Cepheid variable stars in the Andromeda “Nebula.” Scientists had long debated whether this cigar-shaped cloud was an oblique disk around a young star or a vastly farther “island universe” unto itself. By using the intrinsic brightnesses of Cepheid variables to calculate their distances, Hubble finally had observational evidence to prove the latter. The Andromeda Nebula was extraordinarily far away, at least twenty times the Milky Way’s diameter.

After another decade of meticulous observations, the idea of galaxies being organized into a local grouping “sprang from the mind of Hubble as completely as

THE MILKY WAY (above) — our home galaxy — is the second-largest member of the Local Group. This infrared image reveals its thin disk and galactic bulge, along with two satellite galaxies — the Large and Small Magellanic Clouds (lower right). ZMASS/J. CARPENTER, M. SKRUTSKIE, R. HURT

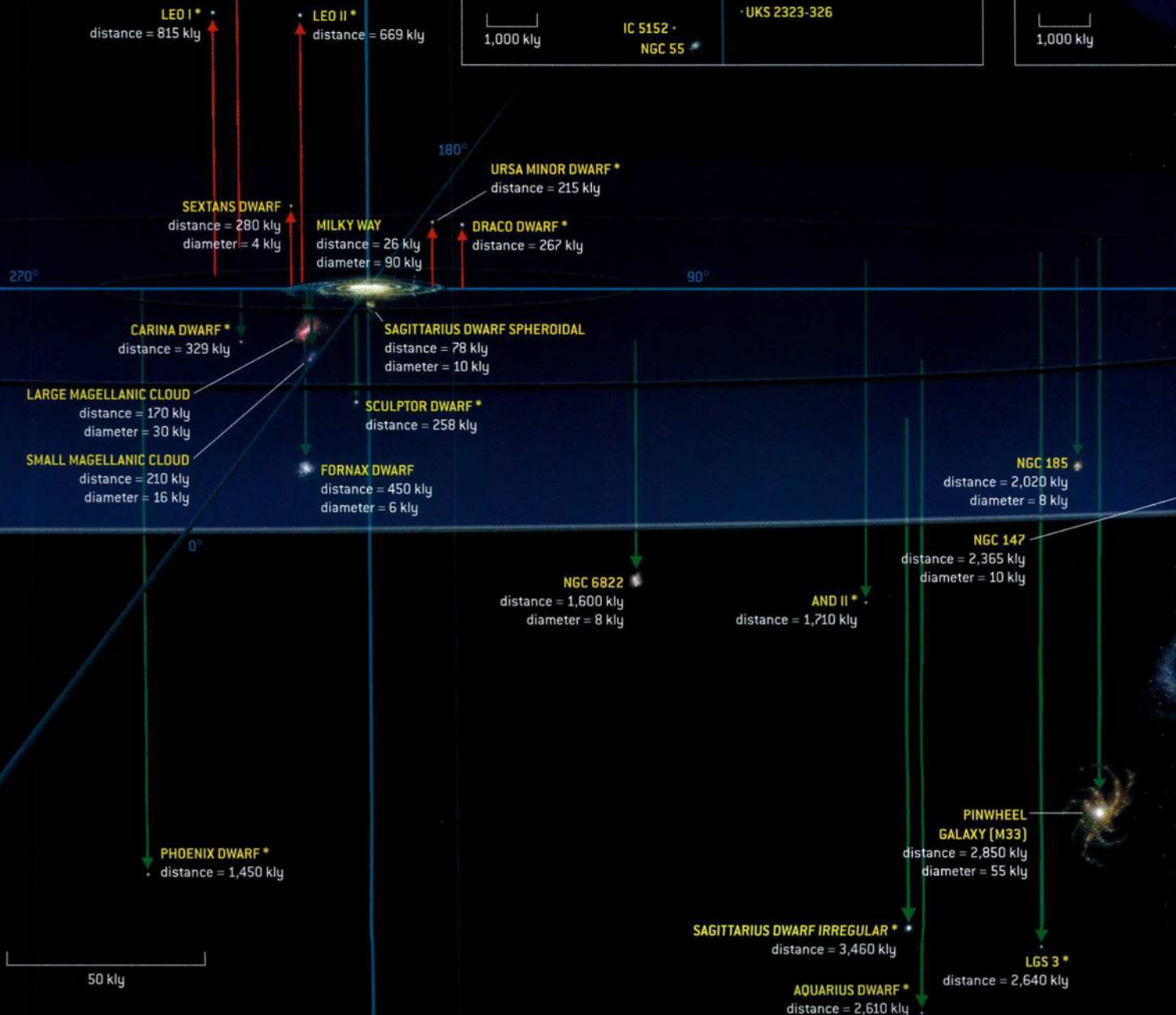
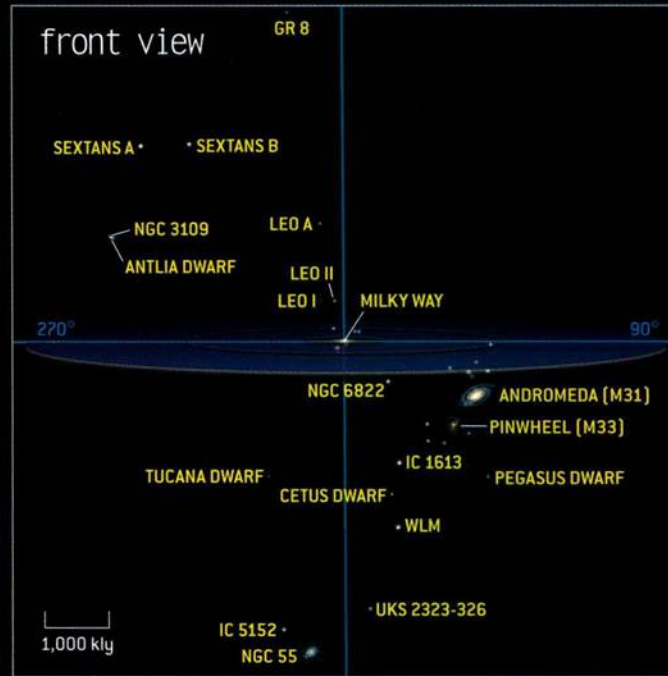
THE ANDROMEDA GALAXY (right) stands as the largest member of the Local Group. This view shows its galactic bulge and the spiral arms that make up its disk. Two of its satellite galaxies, M32 [just left of center] and NGC 205 [at lower right], also can be seen. B. SCHÖENING, V. HARVEY/REU PROGRAM/NOAO/AURA/NSF

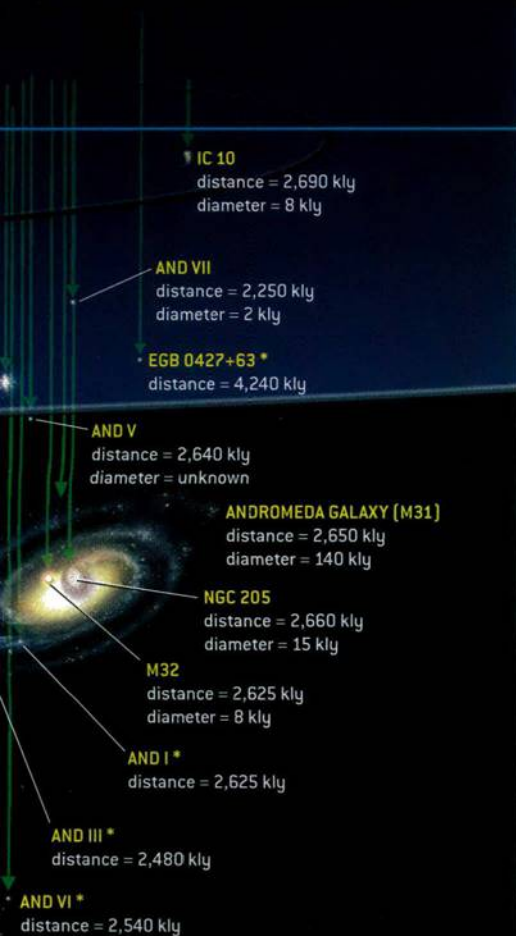


The Local Group

The sizes of the galaxies are enlarged so they can be seen at this distance. They are increased approximately three times their normal size on the large diagram. Both sizes and distances are given in thousands of light-years (kly).

* smaller than 4 kly





ASTRONOMY: ROEN KELLY

the goddess Athena, in full battle garb, sprang out of the head of Zeus in Greek mythology,” says Sidney van den Bergh of the Herzberg Institute of Astrophysics in Victoria, British Columbia. Hubble described it as a fortunate accident that the Local Group contains nearly all the types of galaxies he saw in the universe at large.

Hubble likely never envisioned that eighty years later a telescope comparable in size to the Hooker Telescope, lofted far above the blurry atmosphere — and bearing *his* name — would routinely resolve stars in the Local Group barely $\frac{1}{10,000}$ the brightness of M31’s Cepheids. “The Hubble Space Telescope has opened up the Local Group to completely new, detailed studies,” says William Harris of McMaster University in Hamilton, Ontario. “What we knew about these systems was in a completely different state ten to fifteen years ago.”

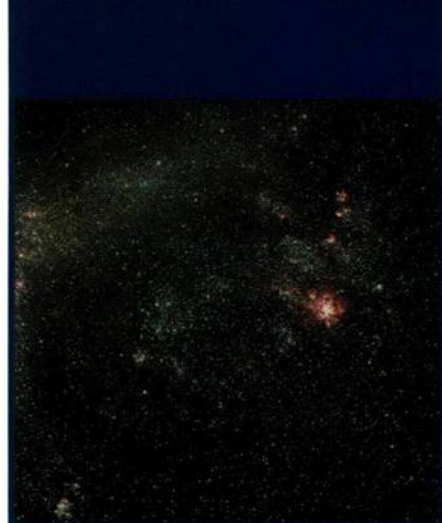
“With Hubble and large, ground-based telescopes, we can get an incredible amount of data on a huge number of individual stars,” says Rosemary Wyse of the Johns Hopkins University. “At last we can try to fit it all together.”

Stars are like clocks in space. The earliest stars — now 13 billion years old — contain few elements heavier than hydrogen and helium. That’s because elements like oxygen, nitrogen, and silicon had not been cooked up yet through nuclear fusion. Younger stars are successively richer in heavier elements forged in earlier generations of stars. So, tracing the abundance of different elements in stars is the astronomer’s equivalent of digging through geologic strata, a way to learn what parts of the Local Group came first.

From chaos to order

Edwin Hubble proposed an evolutionary sequence for elliptical, spiral, and irregular galaxies with his classic Hubble Tuning Fork diagram. But the Hooker Telescope did not have the power to look far enough into the universe to reveal how galaxies might have changed over time.

Today’s Great Observatories Origins Deep Survey, or GOODS program, (using observations by Hubble, the Chandra X-ray Telescope, and soon, the Space Infrared Telescope Facility) shows increasing galaxy size in the universe is consistent with “bottom-up” models of galaxy formation. In these schemes, galaxies grow through mergers and by accreting smaller galaxies.



THE LARGE MAGELLANIC CLOUD, the largest satellite of the Milky Way, contains the brilliant red Tarantula Nebula. NASA/AURA/NSF

Such models support the “cold dark matter” theory, which states dark matter (an invisible form of matter that makes up 90 percent of the universe’s mass) pooled into gravitational “puddles” in the early universe, long before normal matter could. It then collected hydrogen gas that quickly contracted to build star clusters and small galaxies. These dwarf galaxies merged piece by piece over billions of years to build the immense spiral and elliptical galaxies we see today. The forensic evidence in our Local Group allows astronomers to scrutinize the past 13 billion years in a new level of detail. The results agree beautifully with those from the GOODS program, but some mysteries linger.

Most astronomers think the Local Group “turned on” roughly 13 billion years ago, when seedling star clusters that formed from hydrogen gas flowed into dark matter “potholes.” This occurred at the end of the “dark ages,” the brief interval of time when the universe cooled below a temperature of 3,000° Fahrenheit. “We now know a lot of action happened in the first few million years,” says Harris. “Somehow we have to connect all of this into a single formation scenario.”

When the earliest clusters emerged from the dark ages, the Local Group was only 600,000 light-years across, just a quarter of the current distance to the Andromeda Galaxy. Higher density means star clusters must have collided and merged quite frequently. Picture these cluster mergers as many little brooks coming together to form streams, which then converge into a mighty river.

It's raining stars

The Milky Way Galaxy today is usually depicted as a sedate-looking disk, bulge, and halo. A compact disk (CD) makes a useful model. The silvery disk is the approximate diameter-to-thickness ratio of the Milky Way's stellar disk. The central bulge of stars would be a ping-pong ball glued in the CD's center. The galactic halo of orphaned stars and surviving globular clusters is a beach-ball-sized swarm enveloping the CD. Tickertape streamers arranged in a pretzel pattern through this volume would resemble shreds of dwarf galaxies being devoured by the Milky Way. Now imagine another CD inside a beach ball located about 10 feet away: That's the Andromeda Galaxy. Dwarf galaxies would be scattered between these two beach balls out to a distance of about 15 feet.

The emerging view is that early globular star clusters crashed together to build up the Milky Way's central bulge. The Milky Way pulled in surrounding gas, which settled into a vast, thin disk. Cluster collisions scattered stars into a halo, and the disk puffed up, becoming thicker.

Only a fraction of the original globular clusters survive today. Harris compares them to old castles in different states of disrepair. Their ability to survive depends on their mass and trajectory through their host galaxy — either M31 or the Milky Way. Some of the globular clusters are relatively unscathed, some have been torn into star streams.

Recent observations of the Milky Way suggest a complex galaxy shaped by dynamical evolution. "Our galaxy is



ANDROMEDA'S SATELLITE, NGC 205, is one of many dwarf spheroidal galaxies that call the Local Group home. NOAO/AURA/NSF

pretty hungry and is accreting all kinds of satellites in different ways," says Mary Putman of the University of Colorado. Put even more succinctly, "our Milky Way has merged, is merging, and will continue to merge," says Wyse.

Like a toddler with a face full of jam, the Milky Way is a sloppy eater. The halo contains shreds of smaller galaxies being devoured. The disk is warped by passing dwarf galaxies. High-velocity hydrogen clouds far above the galactic plane trace the destruction of these dwarfs, whose debris literally rains down onto the galactic disk.

One of the earliest clues to cannibalism came in 1992, when astronomers discovered a dwarf galaxy merging with the Milky Way. By some contempt of nature, the great star clouds of Sagittarius largely hide this dwarf. "This could be the archetype of larger satellite galaxy mergers that happened in the past," says Steve Majewski of the University of Virginia. Computer simulations show this galaxy is being stretched like taffy as it falls into the gravitational sinkhole of our galaxy.

The most obvious relic of our violent past is the Magellanic Stream, a trail of cold hydrogen that extends across 100° of sky without any obvious stars. The prominent satellite galaxies, the Large Magellanic Cloud and Small Magellanic Cloud, are at the head of the stream, which makes an arc around the south galactic pole.

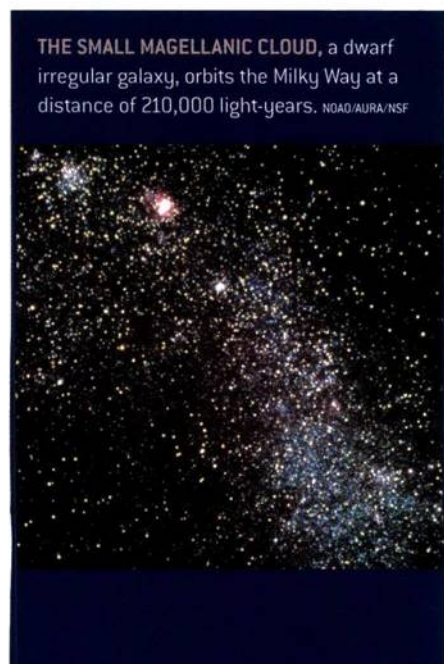
Odd couple

Formation models don't predict two giant galaxies growing next to each other in such an isolated part of the universe. In fact, M31 may have been even closer to the Milky Way at one time.

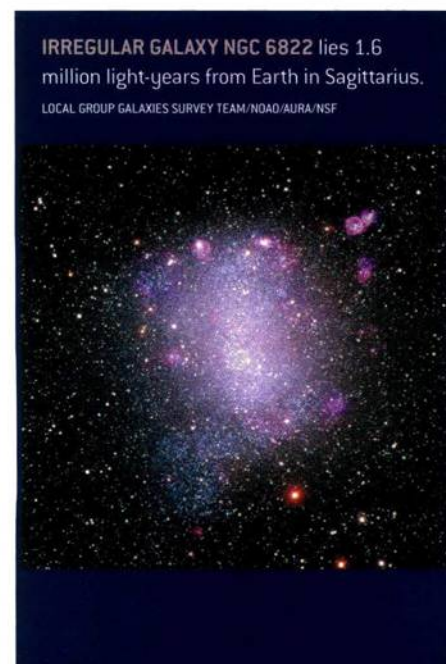
Edwin Hubble would agree that nature was generous in giving us such a close companion to study. Nature also generously tilted M31 nearly edge-on to our line of sight. This allows its halo, bulge, and disk population to be segregated rather easily for study. "The Andromeda Galaxy gives us a more democratic view of stellar populations," says Puragra Guhathakurta of the University of California at Santa Cruz. By comparison, foreground dust and star clouds almost totally obscure the Milky Way's bulge.

We need to look at M31 because our Milky Way "is not typical," asserts Wyse. "It has not done much major merging for quite a while." The Andromeda Galaxy gives astronomers a better view of the complex forensics of cannibalism and large galaxy growth.

Like the Milky Way, M31 contains many globular clusters. One in particular, called G1, may only be *masquerading* as a globular. It might really be the stripped down core of a dwarf spheroidal galaxy shredded by M31. One piece of evidence: G1 contains a 10,000-solar-mass black hole — something astronomers once expected to find only in galaxies. Equally mysterious is M33, a dwarf disk galaxy that has avoided being torn up by M31. "It should not have survived," says Ken Freeman of the Mount Stromlo Observatory in Australia.



THE SMALL MAGELLANIC CLOUD, a dwarf irregular galaxy, orbits the Milky Way at a distance of 210,000 light-years. NOAO/AURA/NSF



IRREGULAR GALAXY NGC 6822 lies 1.6 million light-years from Earth in Sagittarius. LOCAL GROUP GALAXIES SURVEY TEAM/NOAO/AURA/NSF

Ray Villard is public information officer at the Space Telescope Science Institute in Baltimore, Maryland. His previous article was "Unveiling the Dark Universe" in the November 2002 issue.



OUTLYING LOCAL GROUP MEMBER NGC 55, another dwarf irregular, lies nearly 5 million light-years from Earth. NOAO/AURA/NSF

A striking difference is that both young and old stars abound in M31's halo, whereas the Milky Way's halo contains predominantly old stars. This suggests the Milky Way formed in isolation while M31 underwent a major merger that threw a bunch of stars and gas into the halo only 7 billion years ago. (See "Through Andromeda, deeply," September 2003.)

Backyard laboratory

The Local Group serves as an astrophysics laboratory for taking a close-up look at fundamental cosmological mysteries. Our neighborhood offers a sample of the range of massive black holes that emerged in the early universe. Our own home-grown black hole in the galactic core, it's cousin in M31, and smaller relatives in globular clusters M15 and G1 allow astronomers to study black holes in detail.

A landmark census of galactic black holes by astronomers using the Hubble Space Telescope revealed that a black hole's mass is precisely 0.5 percent of the mass of a galaxy's bulge. Amazingly, the black holes found in M15 and G1, which are 10,000 times less massive than a galaxy, also obey this trend. It appears that some yet-to-be-discovered underlying process ties a black hole to its host in a fundamental way.

Astronomers even use the Local Group to reduce the list of candidates for dark matter. Scientists have searched the halo of our galaxy using gravitational lensing, looking for invisible objects that would bend the light of background stars. So far, these searches rule out Massive Compact Halo Objects, hypothetical small,

dark objects, as the last potential hiding place of baryonic dark matter (made of electrons, protons, and neutrons). The dark matter skeleton has been exorcised from the astrophysical closet. It cannot be made of the same atoms that stars, planets, and people are forged from. Instead, it is now a phantom for particle physicists to hunt down.

Living in the Local Group

No doubt, countless extraterrestrial civilizations in the Local Group peruse it with a similar archaeological curiosity and fervor. It is a collective search for our cosmic roots. What's sobering is that planets may have started being made in the Local Group billions of years before our Sun and Earth formed.

Imagine if the Local Group contains even one extraterrestrial civilization billions of years older than ours. However improbable this scenario, such a civilization could have an archive of the evolution of our galactic neighborhood.

We'll need such an *Encyclopaedia Galactica* because the Local Group's history will get ever blurrier to future astronomers. The big makeover comes in 7 billion years, when the Milky Way and Andromeda galaxies will merge. Computer simulations and telescopic images of other mergers give exquisite details of what's in store: Stars will scatter into a huge sphere; long tidal tails will form; the cores will merge. When the central black holes coalesce, the newly forming galaxy will shudder momentarily in the wake of gravity waves rippling time and space.



THE ANTLIA DWARF gives a good idea of what a healthy majority of the forty or so Local Group galaxies look like. ESO



THE MICE, a pair of colliding galaxies, show how the Milky Way and Andromeda may appear in 7 billion years. NASA/ESA/ACS SCIENCE TEAM

In the far future, astronomers will gaze at the sky and see all the way into the core of a new elliptical galaxy. They will have no evidence that there were once two majestic spiral galaxies called the Milky Way and Andromeda by a long-forgotten civilization.

A look at the nearby giant galaxy NGC 5128, better known as Centaurus A, presages the future of the Local Group after the Milky Way and M31 merge. This monster elliptical, no doubt, has grown through major mergers, too. Its appetite hasn't abated. It currently is cannibalizing a wayward disk galaxy, and shreds of others are in its halo. A refueled supermassive black hole at the core spews out a fountain of energy in the form of extragalactic jets.

The Local Group is being pulled toward the Virgo Cluster at the rate of 3 million light-years every billion years. In an accelerating universe, however, we may never get there because the space between the Virgo Cluster and our Local Group will stretch apart at an even faster rate.

After untold billions of years, we will be the singular island universe as some of Edwin Hubble's contemporaries believed. An inky sea of absolute nothingness will surround a single elliptical galaxy of purely ancient red stars and a burned-out supermassive black hole. It will no longer be the universe in a nutshell. To far-future inhabitants, it will be the *entire* observable universe. They will never know the effervescent glory of raw creation and renewal we witness now in our Local Group. ■



Peer into the turbulent future of the Local Group at: www.astronomy.com/toc

Absurd universe

The visible matter of the universe — the part we can actually see — is a surprisingly small piece of the whole. /// BY MICHAEL S. TURNER

Place \$2 worth of pennies in a pile. Select only one penny, preferably a nice, shiny one, and set it apart. Cover the pile of 199 pennies with a cloth. What you've created is a crude model of the universe, where what we see with our eyes is only a small part of what our brain knows to exist.

Sound absurd? On February 11, 2003, the first results from the Wilkinson Microwave Anisotropy Probe (WMAP), an orbiting observatory, showed us what we couldn't see. WMAP, conceived in 1995 and launched in June 2001, was a follow-up to NASA's Cosmic Microwave Background Explorer (COBE), which, in 1992, discovered tiny (0.001 percent) variations in the intensity of cosmic microwave radiation across the sky. These variations provided a map of sorts to what the universe was like some 400,000 years after its beginning. Using this map as a starting point, astronomers predicted the makeup of the universe. What they needed, however, was a better instrument to confirm the prediction.

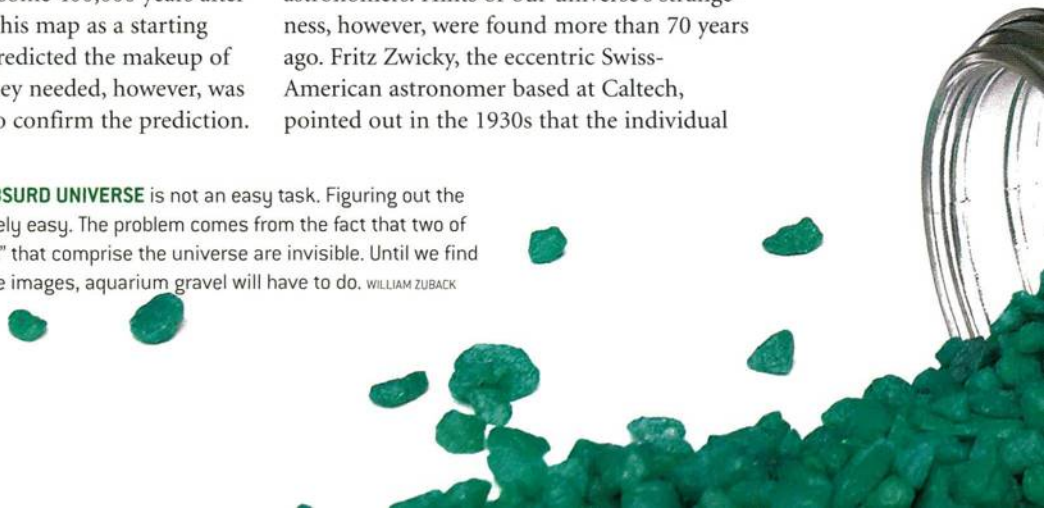
WMAP unveiled — with remarkable resolution — a seemingly absurd universe comprised of 0.5 percent visible matter (stars, dust, and gas), roughly 33 percent dark matter that holds the universe together, and roughly 66 percent mysterious dark energy that is accelerating the expansion of the universe.

With the picture in clear view, scientists have developed a theory: The tiny patterns in the millionth-of-a-degree temperature fluctuations were the seeds of what later became galaxy clusters and other large-scale structures we observe today.

Early ideas

A few decades ago, the idea that the visible universe made up only 0.5 percent of all there is would have sounded ridiculous to most astronomers. Hints of our universe's strangeness, however, were found more than 70 years ago. Fritz Zwicky, the eccentric Swiss-American astronomer based at Caltech, pointed out in the 1930s that the individual

ILLUSTRATING OUR ABSURD UNIVERSE is not an easy task. Figuring out the percentages is relatively easy. The problem comes from the fact that two of the three "ingredients" that comprise the universe are invisible. Until we find a way to print invisible images, aquarium gravel will have to do. WILLIAM ZUBACK



[VISIBLE MATTER]

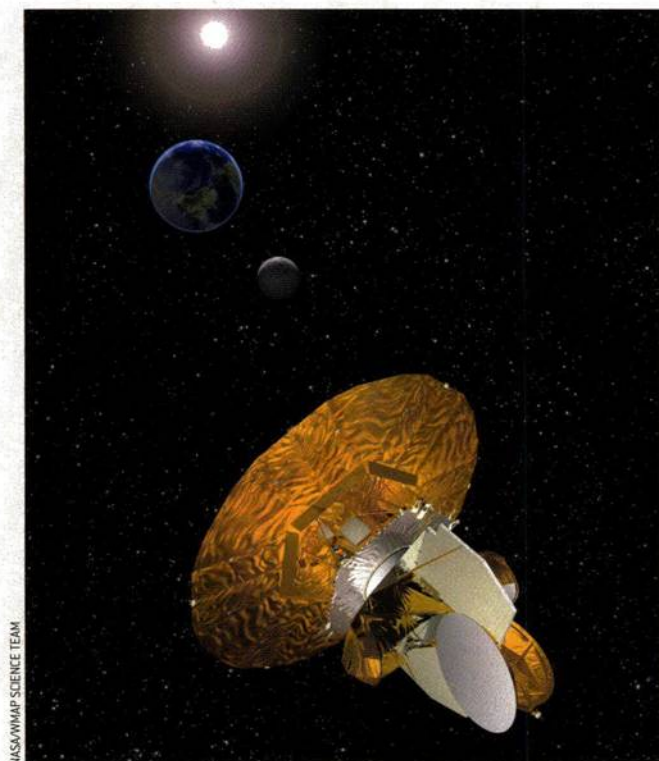
0.5% of the universe is made of baryonic matter, a term referring to the fact that visible matter is composed of baryons, groups of quarks subject to the strong nuclear force.

[DARK MATTER]

33% of the universe is made of material that astronomers call dark matter. Dark matter is similar to baryonic matter because it has mass, and therefore exerts gravitational force.

[DARK ENERGY]

66% of the universe seems to be an unknown type of energy that astronomers call dark energy, some kind of antigravitational force that is accelerating the expansion of the universe.



members of the Coma cluster of galaxies were moving too fast to be bound by the gravitational effects of their stars alone. Without the additional gravity of some unseen form of “dark” matter — perhaps even in the form of billions of small bodies like Jupiter — the galaxies within the Coma cluster would have long since dispersed. Today, astronomers can map the amount of dark matter contained in many galaxy clusters by studying how those clusters bend light from more distant objects.

Clusters were strange, and Zwicky even more — so it was easy to ignore the dark matter problem. However, a complication arose from another direction. In 1964, Bell Lab scientists Arno Penzias and Robert Wilson discovered the cosmic microwave background (CMB) radiation. The Big Bang theory predicts that the early universe was a very hot place. As it expands, however, the radiation within it expands into a larger and larger space and cools. Today the universe is filled with the Big Bang’s remnant heat — the CMB. The CMB contributes only negligibly to the energy content of the universe, about 0.01 percent of the total, but it provides an exquisite record of the universe at a simpler time.

Because the universe is expanding, its radiation is becoming weaker as photons fill an ever-larger space and as each photon’s energy is redshifted. Looking forward, this means the energy of the CMB will become less important; but looking backward, it means that earlier than 10,000 years after the Big Bang, the radiant energy of the CMB was very important. In the early universe, matter was the bit player.

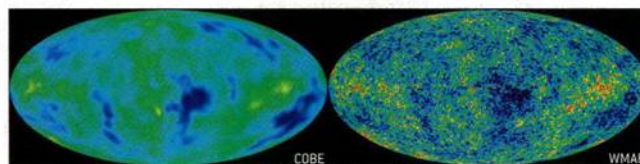
Michael S. Turner is chairman of the Department of Astronomy and Astrophysics at the University of Chicago.

WMAP floats lazily in space in this artist’s depiction (left). Launched on June 30, 2001, WMAP maintains a distant orbit at the second Lagrangian Point, or “L2,” four times farther than the Moon and approximately a million miles from Earth.

Compare the images from WMAP (below right) and COBE (below left). These images show an all-sky picture of the universe when it was very young, only 380,000 years after the Big Bang. In 1992, NASA’s COBE mission first detected tiny temperature fluctuations in the cosmic microwave background radiation (depicted in the image as color variations). This was a landmark discovery. Notice the much higher resolution of the 2003 WMAP image. Because of advances in technology, the WMAP image brings the COBE picture into sharper focus.

WMAP allowed astronomers to observe the first light to break free in the infant universe, the afterglow of the Big Bang. Patterns imprinted on this light reflect the conditions set in motion a tiny fraction of a second after the Big Bang.

The image (below right), the first detailed, all-sky picture taken by WMAP, reveals temperature fluctuations (shown as color differences) more than 13 billion years old that correspond to the “seeds” that grew to become galaxies.



Dark proof

Vera Rubin, an astronomer at the Carnegie Institution, and others brought the dark matter problem much closer to home in the 1970s and 1980s. With the discovery that both stars and clouds of gas farthest from the center of the galaxy are moving too fast to be held by the gravity of just stars, Rubin and her colleagues showed how dark matter actually holds galaxies like our own together. Even at our position in the Milky Way, about half the gravity that keeps us in orbit is due to unseen dark matter.

The late David Schramm showed how the production of the lightest elements, especially deuterium, in the Big Bang could be used to measure the total amount of ordinary matter. The conclusion was shocking — no matter what form it was in, there simply was not enough ordinary matter (and thus gravity) to hold the universe together. WMAP, because of its greater precision, found a clue to this puzzle in the cosmic microwave background radiation — while Carl Sagan was right when he said *we* are made of star stuff, cosmologists now know that the universe is not.

Dark candidates

The infusion of particle physics into cosmology in the 1980s brought a revolutionary idea: Dark matter may exist as particles of a new form of matter. Three particle suspects have emerged: the neutrino (actually known to exist), the neutralino (100 times heavier than a proton), and the axion (one-trillionth the mass of an electron). For now, the neutralino and axion exist only in the minds of particle theorists and cosmologists.

The particle dark matter idea got a boost in 1998. The Super-Kamiokande detector in Japan, studying neutrinos produced in

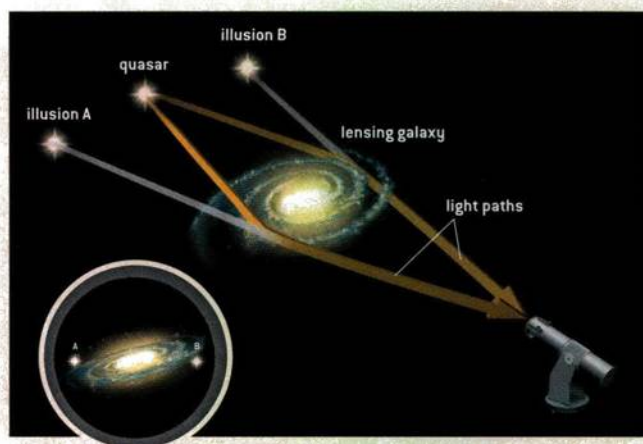
A theoretical lensing galaxy (top right) produces more than one image of an object because the galaxy's gravity bends the object's light around the galaxy in several directions. This effect — the gravitational bending of light — was first predicted by Einstein and explained in his general theory of relativity.

In the 1930s, astronomer Fritz Zwicky put forth the idea that galaxy clusters must contain some form of dark matter. Otherwise, the motions of the individual galaxies within the clusters would disperse the galaxies into space. Because the amount of lensing by galaxy clusters is due to the amount of visible matter plus the amount of dark matter, astronomers can calculate the amount of dark matter galaxy clusters contain.

Lying in the constellation Pegasus the Winged Horse, Einstein's Cross (bottom right) is an excellent example of gravitational lensing. The single quasar, designated Q2237+0305, shows up as four images because of the lensing spiral galaxy between the quasar and Earth. This image was taken by the 3.5-meter WIYN (Wisconsin, Indiana, Yale, NOAO) telescope, on October 4, 1999.

This system also is known as Huchra's Lens, after its discoverer, but more popularly as Einstein's Cross. Einstein postulated this effect as soon as he realized that gravity would be able to bend light and thus could have lens-like effects.

The distance to this lensing galaxy is 400 million light-years, which may sound like a staggering distance until you compare it to the distance of the quasar behind the galaxy. Q2237+0305 is 8 billion light-years distant, twenty times the distance of the lensing galaxy.



TOP: J. RHODES, S. MALHOTRA, I. DELL'ANTONIO (NOAO)/WIYN/NOAO/NSF; BOTTOM: J. RHODES, S. MALHOTRA, I. DELL'ANTONIO (NOAO)/WIYN/NOAO/NSF

Earth's atmosphere by cosmic rays and in the interior of the Sun, showed that neutrinos have mass, albeit very little. Because so many neutrinos are left over from the Big Bang, if a single neutrino has even a tiny mass, all neutrinos combined become players in the cosmic mix. In the spring of 2002, astronomers at the Sudbury Neutrino Observatory in Ontario, Canada, studying neutrinos from the Sun, discovered more evidence that neutrinos have mass. And in the autumn of 2003, two experiments in Japan using human-made neutrinos further strengthened the case that neutrinos contribute somewhere between 0.1 and 5 percent of the total matter of the universe.

The story is not over yet. Neutrinos cannot account for all the dark matter; they appear to be just a cosmic spice. Particle physicists and cosmologists are pinning their hopes on the neutralino and axion, both referred to as cold dark matter. (This name comes from the assumption that dark matter particles were moving slowly when galaxies began to form.) Scientists are trying to produce neutralinos using particle accelerators. Ultra-sensitive instruments are trying to detect axions and neutralinos to see if, indeed, they exist.

Dark energy

Just as many cosmologists and astrophysicists were getting used to the idea of particle dark matter and the fact that we are not made of the primary stuff of the universe, along came dark energy. Two groups of astronomers in the late 1990s, one led by Saul Perlmutter of Lawrence Berkeley Lab in California, and the other by Brian Schmidt of Mt. Stromlo Observatory in Australia, used distant supernovae as standard candles to measure the slowing of the expansion of the universe.

They found, however, that the expansion is not slowing down — it is speeding up — apparently due to the repulsive gravitational action of something that doesn't give off light. This "something" is referred to as dark energy because the way it reacts with the rest of the universe implies a form of energy. If the accelerated expansion continues for another 150 billion years, the sky will darken, with only a handful of galaxies remaining visible.

Where do we go from here?

So here we are in our absurd universe. The Big Bang was a hot beginning, and its radiant energy controlled the universe's first 10,000 years. Stars illuminated the heavens, but they contributed only 0.5 percent of the total mass. The recipe for our universe today is crazier than even Zwicky could have imagined: one-third dark matter, two-thirds dark energy, a pinch of microwave energy, and at least three spatial dimensions. (String theorists insist there must be more.) Dark matter breaks down into 4 percent dark, ordinary matter (the bulk of it in the form of gas that is still too hot to form stars), 30 percent elementary particles, and the rest, simply referred to as cold dark matter, is still to be identified.

The past two decades have seen major advances in understanding how the universe is put together. If we are truly in a golden age of cosmological discovery — and I believe we are — big telescopes, space instruments, and accelerators will, over the next twenty years, help us make sense of this amazing universe in which we find ourselves. ■



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Great balls of fire

Contrary to their reputations, all globular clusters are not created equal. /// BY MARCIA BARTUSIAK

The globular clusters surrounding the Milky Way galaxy, some 150 in all, gleam like cosmic sparklers frozen in time. In each, brilliant specks of light hover around a dense and blazing core. Within a sphere only 100 light-years wide, anywhere from 1,000 to 10 million stars exist.

One of the finest examples lies in the constellation Serpens. The German astronomer Gottfried Kirch and his wife Maria Margarethe first noticed this object on the night of May 5, 1702. In her diary, Margarethe described the compact patch as a “neblichte Sternchen” — a nebulous star. The French comet hunter Charles Messier rediscovered it in 1764 and also was unable to distinguish its clusterlike quality, calling it a “beautiful nebula.” It was fifth on the list in Messier’s famous catalog of nebulae, so it became M5.

Not until 1791 did William Herschel, the most accomplished observer of his time, at last resolve M5 into a compact ball of stars. With his 40-foot-long telescope, the biggest in its day, he counted some 200 stars within it. Herschel already had a theory to explain (and name) this amazing assembly. In a famous 1785 paper in the *Philosophical Transactions of the Royal Society of London* entitled “On the Construction of the Heavens,” he wrote about the formation of nebulae. He imagined a particularly large star gravitationally

attracting others to it “by which means they will be, in time, as it were, condensed about a center; or, in other words, form themselves into a cluster of stars of almost a globular figure . . .”

Today, the Hubble Space Telescope can probe into the very heart of a Milky Way globular cluster. Often described as a mound of diamonds on black velvet, a globular cluster seen with Hubble’s keen eye takes on a far more colorful appearance, with red giants dotting the cluster like large rubies and blue stragglers resembling glittering aquamarines.

Astronomers have renewed appreciation for more than just the clusters’ colors. “At the time I was a graduate student in 1970,”

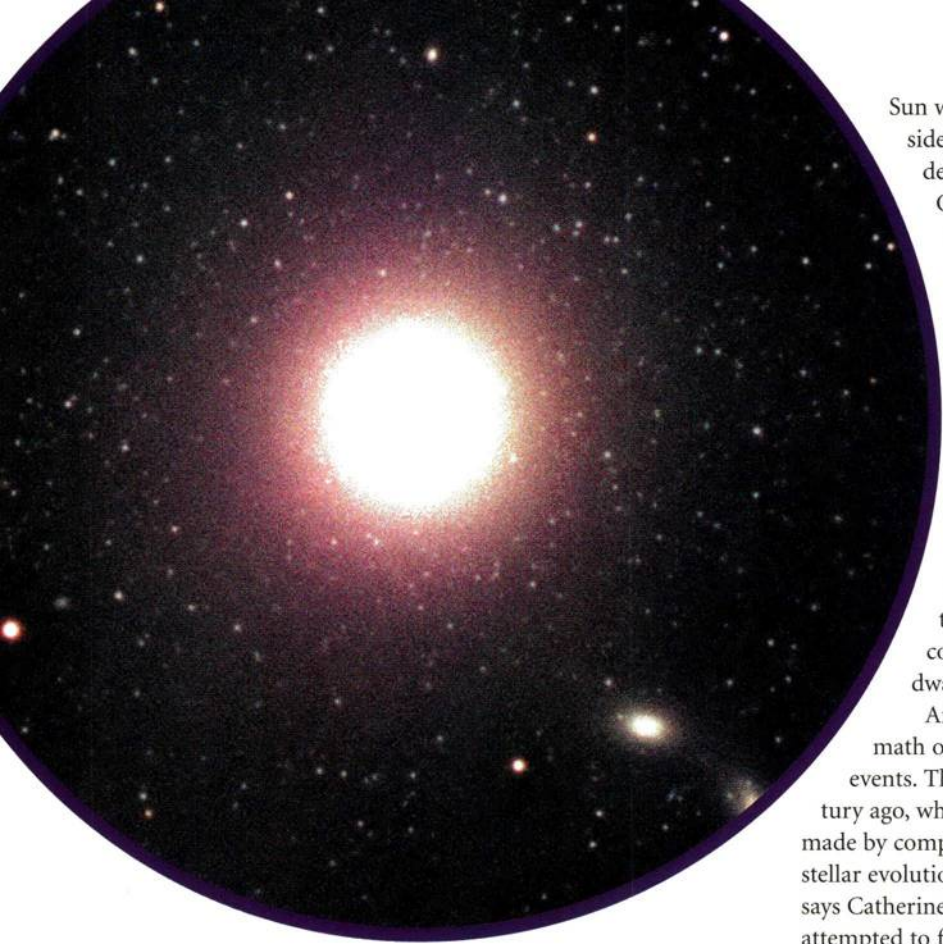
says globular cluster expert William Harris of McMaster University, “globular clusters were thought to be a routine area of study. The clusters were considered among the oldest objects in the universe — all the same from one to the other. Some were bigger, some smaller. It was not a terribly active field.”

But all that’s changed over the last two decades. Electronic digital detectors on ground-based telescopes, coupled with optical and ultraviolet imaging on Hubble, have allowed astronomers to study the magnitudes, colors, and distribution of globular clusters beyond our galaxy, and even beyond the Coma cluster of galaxies. “We were too caught up with what happened here in the Milky



BEAUTIFUL BUT BORING was how many astronomers viewed globular clusters such as M13 (left) until advanced telescopes revealed these stellar communities to be full of surprises. CANADA-FRANCE-HAWAII TELESCOPE/COELUM/J.-C. CUILLANDRE

M5 IN SERPENS (above) was mistaken for a star and a nebula before being identified by William Herschel in 1791 as a “cluster of stars of almost a globular figure.” It lies about 25,000 light-years away and appears to be a ripe 13 billion years old. HILLARY MATHIS (REU PROGRAM)/NOAO/AURA/NSF



M87, a massive, elliptical galaxy near the heart of the Virgo cluster, glows diffusely with more than 10,000 globs. DAVID MALIN/ANGLO-AUSTRALIAN OBSERVATORY

Way,” explains Harris. It seems globular clusters patronize all types of galaxies, although they make up just a tiny fraction of most galaxies’ stellar mass (usually no more than one percent). A dwarf galaxy may claim just one globular cluster, and giant ellipticals, such as M87 in the Virgo cluster, may host more than 10,000 clusters that huddle around the galaxy like a swarm of bees. “We’re finally seeing other neighborhoods and are forced to conclude that there’s a much wider range of globular clusters than we realized. . . . We now have a much larger playground in which to play,” says Harris mirthfully.

Astronomer James Hesser of the National Research Council of Canada agrees. “The new technologies were magic,” he says. “Instead of using insensitive, nonlinear photographic plates to do photometry and then carrying out laborious photoelectric calibrations via single stars, we suddenly could do hundreds of stars quickly and accurately.” The resulting surge of data changed an understanding of these “globs” (as amateur observers like to call them) that had stood for decades.

Early studies

All globular cluster research is inevitably rooted in the observations of astronomer Harlow Shapley, who “cast a long shadow on the field,” notes Harris. “He was the first to talk about globular clusters as a system, a population.” In the 1910s, while at Mount Wilson Observatory in California, Shapley published a series of articles on the Milky Way’s globular clusters. In the 12th paper, he announced what became his most famous discovery: From the distribution of globulars around our galaxy, he concluded that the

Sun was situated not in the galaxy’s center but off to one side of the flat disk of stars. Later, Edwin Hubble detected globular clusters in the nearby Andromeda Galaxy, establishing that globulars were members of other galaxies as well.

Globular clusters were typically defined as the oldest objects in the universe, all predating their host galaxies and all alike. The first hints that not all globulars were created equal arose in the 1940s and ’50s, when a few dedicated cluster observers, particularly N. U. Mayall of California’s Lick Observatory, William Wilson Morgan of Wisconsin’s Yerkes Observatory, and Tom Kinman of the National Optical Astronomy Observatory in Tucson, found evidence that clusters vary, both in content and speed. In 1994, when the Sagittarius dwarf galaxy was discovered as a companion to the Milky Way, it turned out the dwarf’s nucleus was globular cluster M54.

And globular clusters form even today — in the aftermath of recent galaxy interactions, mergers, and starburst events. This finding would have been unbelievable half a century ago, when the first age estimates of globular clusters were made by comparing observations of cluster stars with theories of stellar evolution. “In the early days of globular cluster studies,” says Catherine Pilachowski of Indiana University, “astronomers attempted to find *one* answer to how and when they were made. But now we know there are probably many paths.”

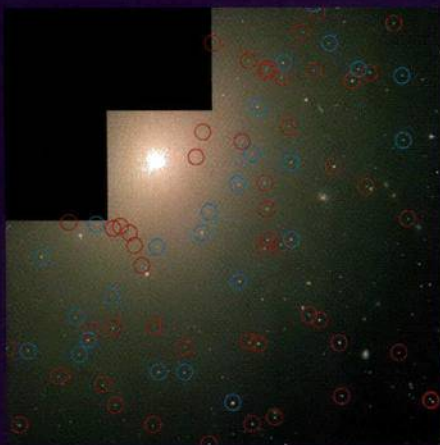
For richer or poorer

Today astronomers view globular clusters as vital relics of the galaxy formation process itself, offering clues on how a particular galaxy arrived at its size and shape.

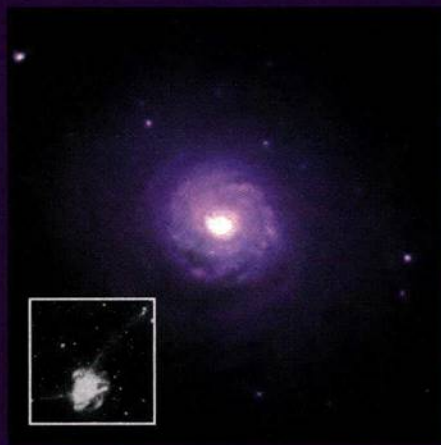
Far from being uniform, globular clusters differ by age and content. Some are “metal poor,” meaning they do not have great quantities of elements heavier than helium, whose most abundant form contains two protons and two neutrons in its nucleus. Because most of the heavier elements were forged by nuclear fusion in stars, metal-poor clusters indicate an early formation from primordial material. Other globular clusters have been found to be “metal rich” (containing one-sixth or more of the Sun’s abundance of higher elements). Astronomers believe metal-rich globs formed after one or more rounds of star formation and stellar explosions scattered heavier elements, like ashes, into space. “These [different types] must represent fairly distinct epochs of cluster formation,” wrote Harris in a 1999 review of the field.

In the Milky Way, the classic, metal-poor clusters reside predominantly in the outer halo of our galaxy and move rather slowly. Metal-rich clusters tend to dwell around the central galactic bulge, orbit more rapidly, and be 1 billion to 2 billion years younger than their metal-poor cousins.

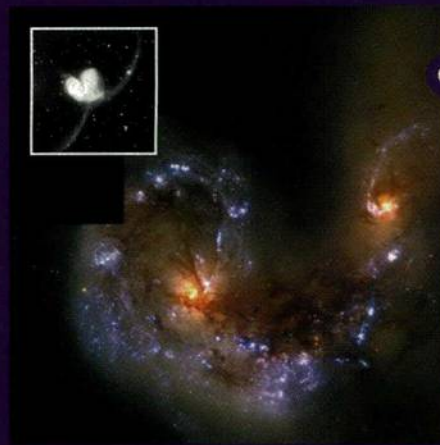
Different types of globular clusters inhabiting different zones might be evidence that the Milky Way underwent separate phases of assembly. The exact details are under debate, but “there’s a growing sense,” says Pilachowski, “that the metal-poor globular clusters were acquired through the *merger of smaller systems* that had already created their globulars.” This meshes nicely with recent observations showing young galaxies being assembled from



A GENERATION GAP exists among globs in the elliptical galaxy NGC 4365. Blue circles represent clusters only a few billion years old, while red circles signify clusters about 12 billion years old. ESO



THE ATOMS-FOR-PEACE GALAXY, NGC 7252, formed from a galactic merger. Forty or so young, bluish globs shine in a gaseous disk in the galaxy's core. B. WHITMORE (STScI)/NASA; INSET: FRANÇOIS SCHWEIZER



THE ANTENNAE GALAXIES, NGC 4038 and NGC 4039, formed gas trails and globular clusters when they merged. Blue globs surround the galaxies' orange cores. B. WHITMORE (STScI)/NASA

smaller fragments. The metal-rich clusters apparently formed later, during the collapse of the larger Milky Way cloud.

The Milky Way's development in phases is still speculative, though, Harris says. "Clusters represent only one percent of the stellar mass of a galactic halo," he points out. "We shouldn't assume that they tell us exactly how galaxy formation took place. They're special objects and may be telling us only part of the story."

In galaxies outside our own, metal-poor globular clusters appear to have similar makeups, which suggests they formed under identical circumstances before their host galaxies were created. Metal-rich clusters, on the other hand, mirror the metallicities of their hosts, varying from galaxy to galaxy. Moreover, the number of metal-rich clusters in any one galaxy appears to be

NGC 7252, whose curved filaments jut out of a fuzzy center. Known as the "Atoms-for-Peace" galaxy for its vague resemblance to the old-fashioned symbol for an atom, NGC 7252 is generally accepted to have formed about a billion years ago from the turbulent union of two galaxies.

But in 1986, when Schweizer attended an astronomy conference in Santa Cruz, California, generating ellipticals from mergers was still considered heresy. Conferees pointed to the "old" globular clusters surrounding elliptical galaxies as evidence of their great age. Schweizer readily responded that some of those globular clusters likely were new — freshly minted during the merger process. "People at this meeting thought I was nuts," recalls Schweizer. "I had never worked on globular clusters, so I knew the

In the early days of globular cluster studies, astronomers tried to find one answer to how and when they were made. Now we know there are many paths.

directly linked to the galaxy's luminosity: the more luminous a spiral bulge or elliptical, the greater number of metal-rich globular clusters surrounding it. What this says about a galaxy's formation and evolution, though, is still being debated. François Schweizer of the Carnegie Observatories believes many of the metal-rich clusters surrounding ellipticals could be fairly new, an idea that provoked gasps among astronomers when he first made the suggestion nearly twenty years ago.

Mergers make gobs of globs

In the 1970s, brothers Alar and Juri Toomre, now a professor of applied mathematics at the Massachusetts Institute of Technology and an astrophysicist at the University of Colorado at Boulder, respectively, carried out computer simulations suggesting elliptical galaxies arose from the merger of disk galaxies — a highly radical notion at the time. Schweizer, however, was greatly influenced by the Toomres' work and soon established a career hunting for examples of merged galaxies. His first successful find was

suggestion might ruin my career." At the time, globular clusters were deemed ancient by definition.

But Schweizer had a hunch: He had seen some weird little dots around both NGC 7252 and another merger suspect (the noted radio galaxy Fornax A) that looked suspiciously like new globular clusters. "Nature knows how to make globular clusters long after the Big Bang — mergers are the process," he explains.

Schweizer was vindicated later by the Hubble Space Telescope as well as larger telescopes on the ground. Looking at the Antennae (NGC 4038 and NGC 4039), a stunning display of two merging galaxies, Schweizer and several colleagues detected thousands of star clusters that had been created within the great clash. When giant clouds of molecular hydrogen embedded in the merging galaxies suddenly experienced rising pressures, they underwent a violent round of star formation.

Within several hundred million years, most of these clusters will be destroyed, their stars dispersed into the field. The most massive stars will die quickly and explode, tearing the cloud apart



47 TUCANAE, an ancient glob in our galaxy, brims with several million stars. Although no planets were detected in the cluster during a week of Hubble observations, several bright, massive stars called blue stragglers [circled] turned up in the cluster's core [right]. Blue stragglers probably result from the merger of two stars. LEFT: DAVID MALIN/ANGLO-AUSTRALIAN OBSERVATORY; RIGHT: R. SAFFER [VILLANOVA UNIV.]/D. ZUREK [STScI]/NASA



GLOBULAR CLUSTER NGC 6397 lies about 8,200 light-years away in the constellation Ara. Every few million years, two stars merge to form a blue straggler [circled]. NASA/HUBBLE HERITAGE TEAM [STScI/AURA]

with supernova blasts. But if enough mass were concentrated in a small volume, some globular clusters would probably survive.

Schweizer and University of Michigan astronomer Patrick Seitzer closely examined older mergers that had time to settle down. In NGC 7252, for example, they found eight young globular clusters that were still very blue, indicating an age of only half a billion years or so (practically newborn in cosmic terms). Many more probably remain hidden by dense clouds of gas. Schweizer estimates that some 500 globular clusters reside around NGC 7252 — half of them old, half of them new.

This leads to the \$64,000 question among globular-cluster observers: Can late mergers explain the thousands of globular clusters found around giant elliptical galaxies? It's still too soon to

triggered the creation of globular clusters but believe merging protogalactic clouds — as opposed to fully formed galaxies — during the first wave of galaxy formation created the bulk of clusters. From this viewpoint, the Antennae and NGC 7252 are mere shadows of what was happening billions of years ago.

Ancient globulars date the universe

The small age difference of the Milky Way's globular clusters supports the idea that the majority of clusters were constructed very soon after the Big Bang. The most pristine clusters, the ones that have less than one percent of the abundance of metals found in the Sun, are around 12 billion to 13 billion years old. This makes them among the oldest objects in the cosmos and, in essence,

We were too caught up with what happened here in the Milky Way. There's a much wider range of globular clusters in other neighborhoods.

tell. "In order to peg the exact ages of globulars in the distant universe, we need larger telescopes to carry out the necessary spectroscopy," notes National Research Council of Canada's James Hesser. Astronomers no longer doubt that mergers can create new populations of globulars. "But I sense they're a minor component" of the overall pool, he says.

Harris concurs, pointing out that it's darn hard to build a tightly bound system like a globular cluster. "Two galaxies merging *might* make around three hundred clusters, but to make thousands would require ten trillion Suns' worth of mass — the raw material out of which the clusters and all other field stars are made," he says. "The only epoch during which such huge amounts of gas were routinely available within galaxies was the protogalactic era itself." Both Hesser and Harris agree that mergers likely

yields a good estimate of the universe's age. The more metal-rich clusters in the Milky Way are only a couple billion years younger. This suggests there was an epoch of massive star cluster formation that began about a billion years after the Big Bang and lasted for a few billion years. It also bolsters views of the early universe, such as in the Hubble Deep Fields, which show galaxies that appear bluer and more agitated in that distant era.

Hesser is pleased that globular cluster ages match estimates of the universe's age calculated from the latest measurements of the cosmic microwave background, the relic radiation from the Big Bang. "Two completely different tests arrive at the same answer!" he points out enthusiastically. That wasn't always the case. For many years, calculations based on standard cosmological models indicated the universe was 10 billion years old, younger than the globular clusters. It was a disturbing paradox: How could stars be older than the universe? It was an irreconcilable age difference, and astronomers knew their understanding of the universe needed

Marcia Bartusiak, a member of Astronomy's Board of Advisors, wrote about compact galaxy groups in the April 2003 issue.

Of the more than 100 extrasolar planets found so far, none may be stranger than the one described by astronomers this past July in the journal *Science*. If the discovery team's claims are true, the newfound planet is not only the oldest and most distant known, it is also the first to be found in a globular cluster, the first to orbit a binary star system, and the only planet whose host is a metal-poor star. The planet is "different from Earth in just about every way," NASA astronomer Anne Kinney says.

The suspected gas giant orbits a tight pairing of a pulsar and a white dwarf within M4, an ancient globular cluster 5,600 light-years from Earth in the constellation Scorpius. Because M4's stars are all about the same age, astronomers believe the planet formed around the same time as the stars — about 13 billion years ago. All of the 110 or so other planets found to date are estimated to be about half that age.

"This implies that planet formation happened very early in the universe," said team member Steinn Sigurdsson of Pennsylvania State University. The globular cluster's stars formed so early that they contain just $\frac{1}{30}$ the Sun's abundance of heavy elements — a surprise to some scientists who believed planets needed more than hydrogen and helium and a sprinkling of heavier elements to form.

The planet's location suggests it's been through a lot in its long life. "There's no way it could've formed in its current position," Sigurdsson said. He and colleagues imagine the planet formed in the less dense, outer regions of the cluster around a star slightly less massive than the Sun. In their scenario, the star and its planet migrated toward M4's core and were captured by the pulsar they now accompany. Eventually, the original host star puffed into a red giant whose material was pulled onto the spinning neutron star. The red giant's remains became a white dwarf, and the pulsar's rotation rate sped up to about a hundred times per second.

Finding the planet (which is too faint to be imaged) took a similarly tortuous route. Discovered 15 years ago, the millisecond pulsar, called PSR B1620-26, emits regular pulses of radio emissions. Variations in these radio waves showed the pulsar was tugged by an object that Hubble revealed as the white dwarf and another, unseen object. Estimated at 2.5 times Jupiter's mass, the third object was inferred to be a planet. It remains about 2 billion miles from the pair (roughly Uranus's distance from the Sun), orbiting the two dead stars once a century.

Carnegie Institution astronomer Alan Boss, whose own theory suggests planets don't need rocky cores but can form quickly from gas alone,



THE OLDEST KNOWN PLANET orbits a binary system made of a pulsar and a white dwarf (circled) in globular cluster M4.

NASA AND H. RICHER (UNIVERSITY OF BRITISH COLUMBIA)

called the discovery "a stunning revelation." But Mario Livio, head of the science division at the Space Telescope Science Institute, isn't 100 percent sold on the "Methuselah" interpretation. "I can definitely think of scenarios in which [the planet is younger than its host star]," he says. "Given that it is associated with a pulsar, there was a supernova involved. Supernovae can produce huge amounts of dust, and dust can [in principle] form planets." — *Vanessa Thomas*

to be amended. Help arrived in 1999 with the discovery that the universe is accelerating, its rate of expansion growing faster and faster due to the presence of "dark energy" that appears to pervade space-time. With this added energy gradually boosting cosmic expansion over the eons, the universe was found to be older, eliminating the paradox.

At a conference on globular clusters a few years ago, Hesser made a confession to his colleagues: "I sometimes get the feeling — perhaps some of you do, too? — that I'm not doing real astronomy (for example, the quest for quasars, primeval galaxies, etc.) . . . Tonight, however, armed only with binoculars and a chart from any good sky atlas, you can view a majestic object whose chemistry suggests it formed [very soon after the Big Bang]: M15 . . . and it's only a few kiloparsecs distant!"

Astronomy's own Cirque du Soleil

Globular clusters' use as cosmological markers sometimes overshadows their uniqueness as celestial objects. With stars packed in like subway commuters at rush hour, a globular cluster offers a far more exotic environment than the staid suburbs of the Milky Way disk. Here in the disk, the Sun's closest stellar neighbor, Alpha Centauri, is some 4 light-years away. But if the Sun were located in the center of a globular cluster, it would have a bustling community of 100,000 or more stars closer than Alpha Centauri, lighting up Earth's sky during both day and night. Near-misses between stars would be commonplace.

What holds these stars together so compactly? Powerful computer simulations have begun to answer this long-held mystery.

A cluster in its youth does not just sit; it evolves as kinetic energy is exchanged continually between the stars. Lower-mass stars rev up their velocity and eventually "evaporate" out of the system, while higher-mass stars lose energy and sink toward the center. Over time, the outskirts of a cluster spread out, and the core gets denser, creating the hallmark spherical shape of a globular.

Why doesn't the entire globular cluster completely collapse into a black hole as it shrinks? Simulations show that before this happens, some stars begin to interact and form binary systems, which puts a stop to the crunch. Like partners in a fast-paced square dance, these stars swiftly swing around one another, sometimes pairing up for good or, on rare occasions, merging. That explains the mystery of "blue stragglers." Long seen in clusters, these massive stars are bluer and brighter than the average main sequence star; astronomers now realize they result from mergers of two smaller stars. "They stand out very easily," notes McMaster University's William Harris. "They're rare but easy to spot."

And blue stragglers aren't even the most exotic characters in these jam-packed systems. X-ray telescopes reveal the truly bizarre: cataclysmic variable stars, millisecond pulsars, and neutron-star binaries. The oldest known planet recently turned up around a pulsar/white dwarf binary in the relatively nearby globular cluster M4 — the first time a planet has been found in a glob (see above). Says Harris, "The field has opened up in ways that no one had imagined." ■



For a list of where to find the sky's most beautiful globular clusters, visit our web site at www.astronomy.com/toc

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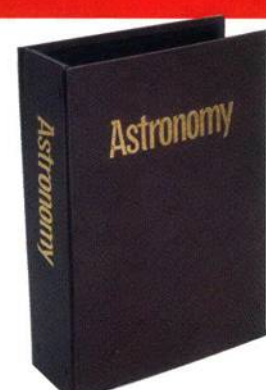
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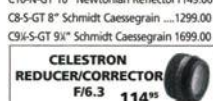
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NOVEMBER 03

Comet Encke brightens significantly while Mars continues to fade and shrink. Late autumn also sees Venus start to ascend her throne as the evening star.

Lunar totality strikes again

For the second time this year, observers in eastern North America have front row seats for a total eclipse of the Moon. Earth casts its shadow on the Moon, turning our celestial neighbor a beautiful coppery-red. ☾ In the early evening of Saturday, November 8, a dark bite will appear on the left side of the Moon and slowly broaden to cover the whole disk by 8:06 P.M. EST.

With the bright lunar surface in darkness, you'll see that the shadow is not totally black, but a dim shade of red. Somewhat like the Cheshire Cat, the Moon's southern limb will show a brighter smile because it lies nearer the shadow's edge.

An awesome sight at any time, a dark, star-filled sky is glorious when you throw in a total lunar eclipse. At first, the bright sky hides our galaxy's river of stars, but as the Moon rapidly fades into the eclipse, the Milky Way brightens into magnificence. Make a point of watching from a dark, rural location if you want to see the Milky Way.

West of an imaginary line that runs from Texas to Saskatchewan, the partially eclipsed Moon rises just as the Sun sets. Europeans will be able to view all of this month's show (unlike May's total lunar eclipse) in the wee hours before dawn on the 9th.

If you imaged last May's eclipse, compare the size of the Moon then with what it is now. Six months ago the Moon was at perigee, its closest point



A TOTAL LUNAR ECLIPSE graces the November sky, recalling this view from September 1996 — except the bright limb will be reversed. JERRY SCHAD

to Earth, but now it is near apogee, its farthest distance. Even through the eyepiece, our neighbor should look noticeably smaller.

Mars may be getting both dimmer and smaller, but don't give up on it yet. It's still big enough to reveal surface and cloud features to the patient observer. By next month, however, only sharp-eyed astronomers and CCD imagers will be able to tease out any but the most obvious details.

Are you ready for the return of the evening star? Venus has just begun a seven-month show that reaches its peak next spring. Right now, it appears low in the southwest after sunset. Each day, it climbs slowly from the bright yellow horizon into the fainter orange glow. You may need binoculars to find Venus at first, but then you should have little trouble spying it with the naked eye.

Jupiter and Saturn lie in the morning sky and are best seen

near dawn, when they are highest. Fortunately, dawn comes progressively later as we head toward winter.

Two stars will glide behind Saturn's rings this month. Telescopic observers should be able to detect individual ringlets as they make the star wink on and off in a frenzy of activity. See "Diamonds in the rings" on page 76 for complete details about the events of November 14/15 and 24/25.

The Leonid meteor shower may have finished roaring, but it's still worth watching for the softer purr. The peak of the annual shower arrives on the night of November 17/18. The first shooting stars will streak across the sky around 11 P.M., when Leo rises, then climb to a peak of 20 to 30 meteors per hour after midnight.

Periodic comet 2P/Encke brightens this month into a nice sight in small backyard telescopes. Its high speed relative to Earth makes it appear to zip across the evening sky from northeast to west in the matter of a month. It starts near the Blue Snowball Nebula, slides past the filamentary Veil Nebula, and pierces the Coat-hanger. This is just the start of an extended comet observing season; two more dirty snowballs stand poised to become visible to the naked eye this coming spring.

9 P.M. on November 1
8 P.M. on November 15
7 P.M. on November 30

The all-sky map shows how the sky looks at

9 P.M. on November 1
8 P.M. on November 15
7 P.M. on November 30

Planets are shown at midmonth

This circular all-sky map illustrates the night sky as seen from Earth's surface, framed by a horizon with trees and grass. The map features numerous constellations labeled in Latin, such as Ursa Major, Draco, Cepheus, Cassiopeia, Andromeda, Perseus, Triangulum, Aries, Taurus, Orion, Eridanus, Fornax, Sculptor, Phoenix, Grus, Piscis Austrinus, Aquarius, Uranus, Equuleus, Lacerta, Cetus, Lynx, Camelopardalis, and Capella. Stars are depicted as white dots of varying sizes, representing their magnitudes. Several deep-sky objects are highlighted with specific symbols: open clusters (dashed circles), globular clusters (circles with a cross), diffuse nebulae (squares), and planetary nebulae (circles with a central dot). Planets are indicated by small circles with labels: Mars (Mars), Jupiter (Jup), Saturn (Sat), Uranus (Uranus), and Neptune (Nept). The ecliptic is shown as a prominent curved line across the map. The background is a dark blue gradient, suggesting the vastness of space.

Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula

 Sirius
 0.0
 1.0
 2.0
 3.0
 4.0
 5.0

 Open cluster
 Globular cluster
 Diffuse nebula
 Planetary nebula
 Galaxy

This map portrays the sky as seen near 35° north latitude at times shown in the upper left corner of the page. Located just outside the map are the four directions: horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

november 03



W

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						 [01]
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 [23]	 [24]	 [25]	 [26]	 [27]	 [28]	 [29]
 [30]						

- 01** The Moon passes 5° south of Neptune, 1 A.M. EST
- 02** The Moon passes 5° south of Uranus, 10 A.M. EST
- 03** The Moon passes 3° south of Mars, 4 A.M. EST
- 08** Full Moon is at 8:13 P.M. EST; total lunar eclipse
- 10** Venus passes 4° north of Antares, 2 A.M. EST
- The Moon is at apogee (252,464 miles from Earth), 7:04 A.M. EST
- 13** The Moon passes 5° north of Saturn, 2 P.M. EST
- 16** Comet 2P/Encke passes closest to Earth (24.2 million miles away), 9 P.M. EST
- Last Quarter Moon is at 11:15 P.M. EST

- 18** Leonid meteor shower peaks
- The Moon passes 4° north of Jupiter, 11 A.M. EST
- 23** New Moon is at 5:59 P.M. EST; total solar eclipse
- The Moon is at perigee (221,712 miles from Earth), 6:16 P.M. EST
- 24** The Moon passes 0.3° south of Mercury, 10 P.M. EST
- 25** The Moon passes 2° south of Venus, 1 P.M. EST
- 28** The Moon passes 5° south of Neptune, 9 A.M. EST
- 29** Asteroid Amphitrite is at opposition, 7 A.M. EST
- The Moon passes 5° south of Uranus, 5 P.M. EST
- 30** First Quarter Moon is at 12:16 P.M. EST

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and color



To locate the Moon in the sky, draw a line from the phase s

PLANETS

Date

Magnitude

Angular Size

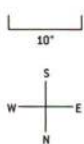
Illumination

Distance (AU) from Earth

Distance (AU) from Sun

Right Ascension (2000.0)

Declination (2000.0)



MERCURY

November 15

-0.5

4.9"

95%

1.383

0.464

16h07.0m

-22°30'

MERCURY

November 30

-0.5

5.6"

82%

1.198

0.415

17h42.4m

-25°48'

VENUS

November 15

-3.9

10.9"

92%

1.530

0.728

16h54.4m

-23°24'

MARS

November 1

-1.2

15.0"

89%

0.626

1.408

22h39.4m

-11°01'

MARS

November 30

-0.4

11.2"

87%

0.840

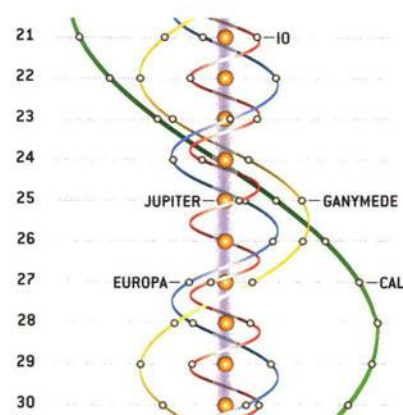
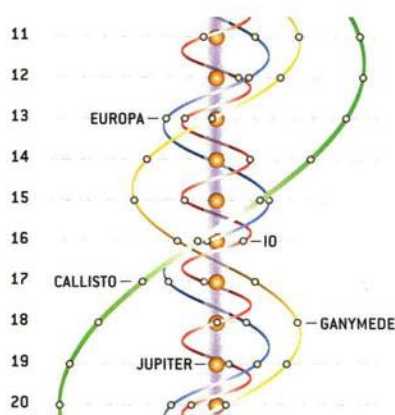
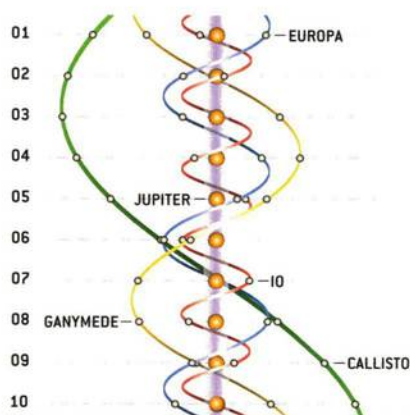
1.436

23h27.4m

-4°31'

Jupiter's moons

Dots display positions of Galilean satellites at 5 A.M. EST on date shown. South is at top to match the view in a telescope.



THE DEEP SKY

Comet Encke swoops south and west along the spine of the Milky Way this month, highlighting a number of interesting and beautiful deep-sky objects.

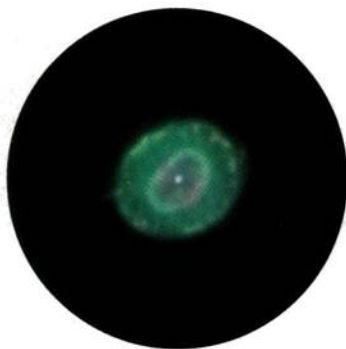
Comet cuts the Coathanger

Second to the total eclipse of the Moon, the most interesting sky event for Northern Hemisphere observers this month is arguably the passage of Comet 2P/Encke through the Coathanger asterism on Saturday night, November 22.

What's an asterism? It's not a constellation, but rather a group of stars that forms an eye-catching pattern (like the Big Dipper) or resembles a loose cluster. For more than a century, astronomers thought the Coathanger was an organized group and cataloged it as Collinder 399. Guidebooks popularized it as both Brocchi's Cluster and the Coathanger.

In the mid 1990s, however, the Hipparcos spacecraft took precise positional measurements of more than 100,000 stars, including many in the Coathanger. The data proved that the stars are unrelated. But the poets at heart still see a thing of beauty, thanks to its recognizable shape and perfect size for binoculars. Most backyard telescopes have a too narrow field of view, allowing observers to see only four or five stars at once.

Comet Encke comes within binocular range of the Coathanger on November 20. European observers get to see



THE BLUE SNOWBALL NEBULA

(above) receives a visit from Comet Encke this month, as do the Coathanger (top right), and the Veil Nebula (bottom right).

ABOVE: NOAO/AURA/NSF; TOP RIGHT: MICHAEL STECKER; BOTTOM RIGHT: CHUCK VAUGHN

the comet's core pass right through the asterism on the 22nd, while North Americans are treated to the sight of the comet's tail sliding among the asterism's bright stars.

Earlier in the month, Encke passes near the Blue Snowball Nebula and the Veil Nebula. See page 65 for a detailed chart showing the comet's path past these deep-sky wonders.

A real cluster

Just off the eastern edge of the Coathanger lies a real star cluster, NGC 6802. It forms a small box aligned north-south and about $\frac{1}{3}$ the apparent size of the Moon. On a dark, moonless night away from the city, a 4.5-inch reflector catches the soft glow at 32x. Pushing the power to 150x starts to bring out individual stars, although the overall view proves more satisfying at 90x because you're



not straining to see the faint specks. The cluster exudes a definite charm in large apertures thanks to its sparkling stars and striking shape.

Piazzini's "Flying Star"

On the evening of November 12, Encke cruises near the beautiful binary star 61 Cygni. Any backyard telescope at low power will separate the pair easily. From our earthly perspective, only five stars appear to move faster across the sky than 61 Cygni's 5.3" per year.

Italian astronomer Giuseppe Piazzini first called the world's attention to 61 Cygni in 1792. Nearly fifty years later, German astronomer and mathematician Friedrich Bessel accurately measured 61 Cygni's much smaller side-to-side shift. Caused by Earth's movement around the Sun, this so-called parallax was only 0.29". Modern visual observers are happy under conditions that let them resolve 0.5". As a comparison, the gap between the stars is 30".

Martin Ratcliffe is former president of the International Planetarium Society. **Alister Ling** is a meteorologist with Environment Canada.

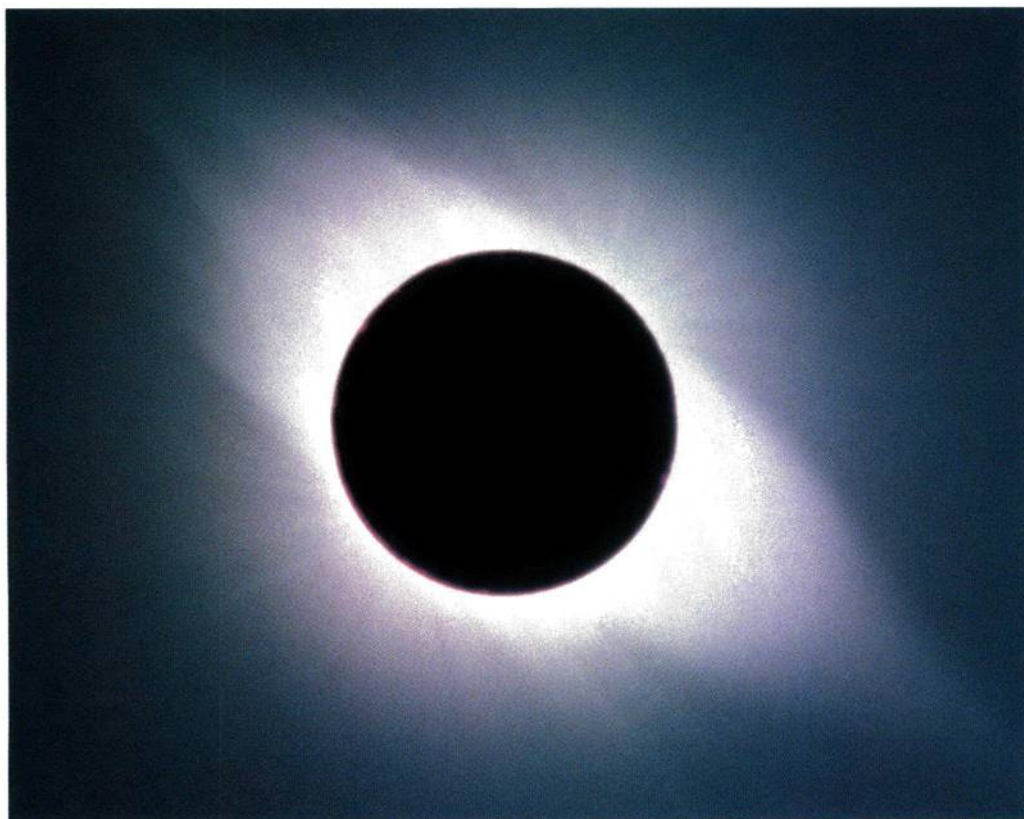
THE PLANETS

A total lunar eclipse likely will dominate the minds of observers in November, but don't miss Venus rising into prominence or Saturn displaying its magnificent rings.

November 8 brings the second total eclipse of the Moon visible from the United States this year. The ruddy Moon makes a nice companion for Mars, which remains conspicuous but, as it moves farther away from Earth, shrinks noticeably when seen through a telescope. The spectacular views common in recent months are coming to an end. However, other planetary sights enter the night's stage. Venus returns to the evening scene, and Mercury joins it toward the end of the month. Meanwhile, Saturn climbs high in the morning hours as Jupiter adorns the pre-dawn sky.

North America experiences its second total lunar eclipse of 2003 on the evening of November 8 (it occurs on the morning of the 9th in Europe and Africa). While East Coast observers get to see the whole event, West Coast viewers see totality in the waning stages of evening twilight. Totality lasts only 25 minutes, with maximum eclipse occurring at 8:18 P.M. EST. The relatively short duration of the total phase results from the Moon passing through the southern part of Earth's shadow. The Moon's southern limb will remain relatively bright; during last May's eclipse, it was the northern limb that stayed bright.

The first hint of the eclipse arrives with the onset of the penumbral phase at 5:15 P.M. EST. First contact with the edge of Earth's dark umbral



THE SUN WILL DISAPPEAR, except for its stunning, ethereal corona, for observers who make the long trek to the frozen continent of Antarctica on November 23. ROBERT SLOBINS

shadow comes at 6:32 P.M. EST, followed by the onset of totality at 8:06 P.M. EST. Expect a fairly bright eclipse because the Moon doesn't venture too deeply into the shadow. The partial phase ends at 10:04 P.M. EST, and the penumbral eclipse wraps up at 11:22 P.M. EST.

The eclipse takes place against the starry backdrop of Aries the Ram, exactly opposite Libra, where last May's eclipse appeared. Successive solar or lunar eclipses typically take place six months apart. The

ecliptic — the apparent path of the Sun across the sky — and the Moon's orbit intersect at two points called nodes. When the Moon lies at one of the nodes at either New or Full Moon, an eclipse occurs. If an eclipse happens in a particular month, then another eclipse (not always of the same type and often not visible from the same region) will take place six months later.

A total eclipse of the Sun also occurs this month, on November 23. Unfortunately, you have to be in Antarctica to

see it. (A partial eclipse can be seen from most of Australia and New Zealand.) Small groups plan to travel to the path of totality, and *Astronomy* will bring you images as soon as they are available.

You should be able to spot **Venus** as it makes a brief appearance in the early evening sky. It remains low, hugging the southwestern horizon until it sets about an hour after the Sun. It shines so brilliantly, however, at magnitude -3.9 , that it can pierce even fairly bright twilight.



Look for a slender crescent Moon a mere 4° to the left of Venus on November 26.

After you've found Venus, scan one binocular field to the lower right and you should see **Mercury**. The innermost planet shines at magnitude -0.5 . For a better view, wait until it reaches greatest elongation in early December.

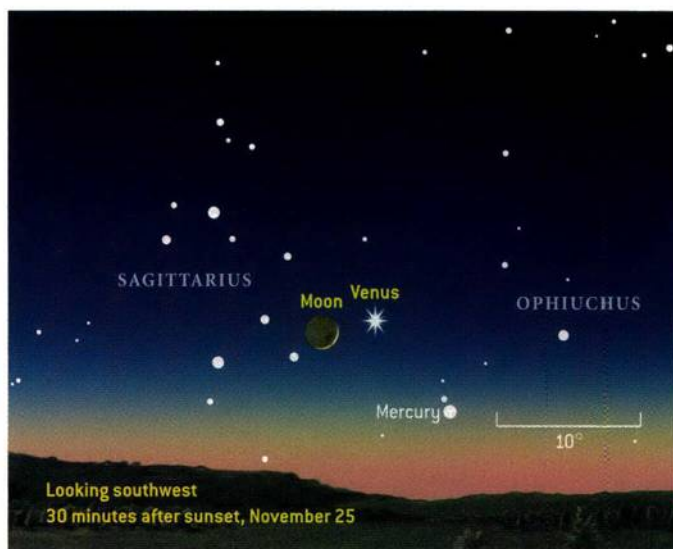
Once the sky grows darker, **Mars** should be your principal target. It spans a still-healthy $15''$ on November 1, but it's shrinking fast because Earth travels around the Sun faster than Mars does. The Red Planet lies 58 million miles from us on the 1st and 20 million miles farther by month's end. This shaves another $4''$ from its apparent diameter, making it increasingly difficult to discern surface features. During the course of November, Mars fades by a factor of two, going from magnitude -1.2 to magnitude -0.4 .

On the evening of November 1, ruddy Mars lies about 20° to the upper left of the First Quarter Moon. That same

night, you can use these two bright objects to locate fainter **Uranus**. The gas-giant planet lies one binocular field to the upper left of the Moon. Simply find the midway point between the Moon and Mars and look above it. Glowing at magnitude 5.8, Uranus can be seen clearly in binoculars. With the glow of the Moon not far away, there's less chance of confusing Uranus with fainter stars, making it an easy target. In a telescope, look for the planet's distinctive blue-green disk, which measures $3.6''$ across.

Neptune also lies nearby, but it's more of a challenge to see. It likewise appears about one binocular field from the Moon on the 1st, but toward the upper right. The distant planet lies 3° west of 4th-magnitude Theta (θ) Capricorni, in the same low-power telescopic field of view as 19 Capricorni. It glows at magnitude 7.8 and spans just $2.3''$, barely discernible in a small telescope.

By around 8 P.M. local time, **Saturn** clears the eastern horizon. Joining Saturn are the



twin stars of Gemini: Castor and Pollux. Shining at magnitude -0.2 , Saturn puts on a fine, late evening display, although it appears higher and sharper after midnight.

Any telescope will show Saturn's rings easily. Although the rings prove mesmerizing, it's worth looking for the planet's moons as well. In particular, 8th-magnitude Titan can be glimpsed easily as it orbits Saturn once every 16 days. Saturn will reach the peak of its current apparition

in December. It comes to opposition on the last day of the year, which places it due south and high in the sky at local midnight.

Jupiter rises after 2 A.M. when November begins and just after midnight by the 30th. The planet shines at magnitude -1.9 , making it the brightest point of light in the morning sky. It lies beneath the hind legs of Leo the Lion. The planet spans an easy-to-view $35''$, which is more than twice the apparent diameter of Mars.

METEORS AND MOONS

Although the Leonids should be down from the high rates of the past few years, it's always a shower worth viewing. Meanwhile, western Mare Tranquillitatis offers several intriguing craters for backyard observers.



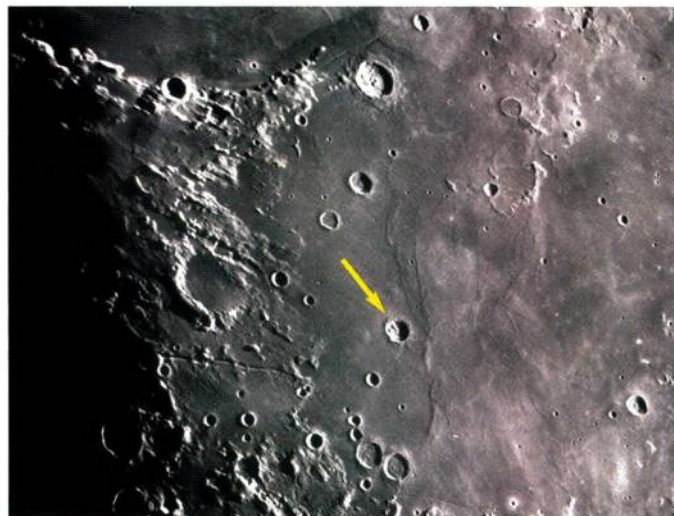
A LEONID FIREBALL appears poised to pierce Orion's heart on an early morning in November. JAMES HAMMOND

Into the Lion's lair

After several exceptional years, the Leonid meteor shower should calm down in 2003. Yet no one knows for sure what the shower has in store for us. Estimates range from a few meteors up to hundreds of meteors per hour at the peak. Predicting meteor rates, particularly for the highly variable Leonid shower, is akin to

estimating the number of snowflakes that will fall on an area of ground: You simply can't know until it's all over. And in the case of the Leonids, only those outside observing will find out what happens.

The remarkable activity seen during the past few years came about because Earth crossed through regions that the shower's parent comet,



THE CRATER ARAGO (arrow) highlights the western shore of Mare Tranquillitatis. FROM CONSOLIDATED LUNAR ATLAS (LPL/UA)

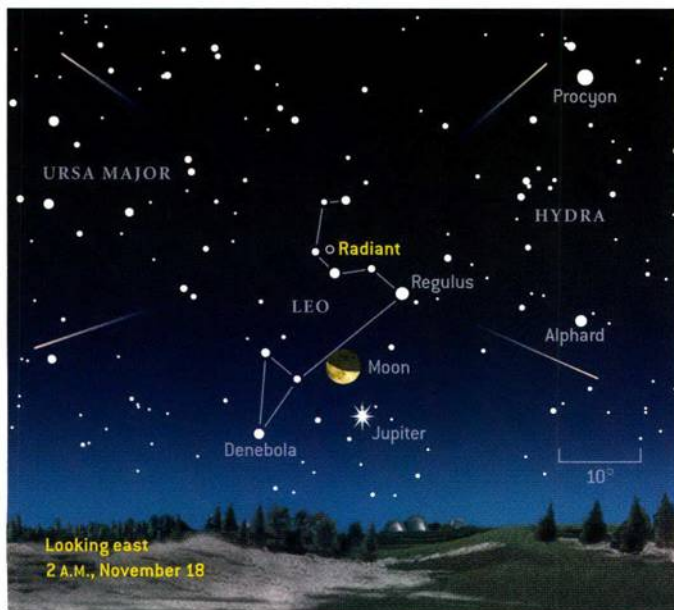
55P/Tempel-Tuttle, had visited. This year, the timing of Earth's passage across the comet's orbit favors observers in Europe. They should see the peak before dawn on November 18. For North America, the peak arrives the previous evening, although the best views still should come after midnight. The Last Quarter Moon interferes somewhat, but the brighter Leonids should shine through nicely.

Moon feature: Arago

Set your sights this month on Arago, a distinct crater that sits on the western side of Mare Tranquillitatis. Many smaller craters join this 16-mile-wide impact site on a curious moonscape. Sunlight first catches this crater six days after New Moon. One day later, a small ridge that connects Arago's northern wall to its

central peak shows up clearly. A complex series of ridges lies east of the crater. These appear most prominent on a six-day-old Moon, when sunrise reaches the region. Although they remain visible the next day, they will have started to blend into the lunar surface.

The ridges extend far to the north, up near Maclear, a polygonal crater with low walls. To Maclear's southwest lies Sosigenes, a crisp, circular crater some 11 miles across. A long rille system cuts through Sosigenes A, a smaller crater located to the south-southeast of its namesake. A 9-mile-wide circular crater named Manners lies just southwest of Arago. Due west of Arago, look for subtle patterns in the lava before the terrain reaches the mountains farther west. To really get to know this region better, try to sketch it.



COMETS AND ASTEROIDS

Comet paradise here we come — from the end of October through next June, we should have at least three nice comets to observe.

Encke's great sweep

In contrast to the slow arcs of planets and asteroids, a nearby comet sweeps quickly across the sky. Along the way, the comet invariably slides past several beautiful deep-sky objects, making for some splendid photo opportunities. Throw in a total eclipse of the Moon, and you'll really have to mark up your calendar to take in all the November sky events.

The top comet story of November has to be the return of 2P/Encke. Encke completes one orbit of the Sun every 3.3 years — the shortest period of any known comet. That's the chief reason it has been seen on more returns (over fifty) than any other comet. Encke stands as one of the few comets named not for its discoverer but for the person who calculated its orbit. French observer Pierre Méchain first spotted the comet on January 17, 1786. But it took more than thirty years before German astronomer and mathemati-

cian Johann Encke calculated an accurate orbit for it.

Some of Comet Encke's apparitions hit their peaks during our daytime, leaving observers out of luck. But this year, Earth is nicely placed for a broadside view during the evening hours. Encke is heading toward its peak just inside Mercury's orbit in late December. For us, the best views will come in November and early December when the comet remains fairly high in the evening sky.

Strap yourself in for a fast ride. On November 2, Encke lies just 3 Moon-widths north of the Blue Snowball Nebula (NGC 7662), a small but high-surface-brightness gas cloud. A waxing gibbous Moon will hide Encke's short tail, but its core should appear about the same brightness as the nebula.

On the night of the total lunar eclipse, November 8/9, you have a perfect opportunity to see just how moonlight affects the visibility of a



COMET ENCKE APPEARS BEST in November, when it should reach 6th magnitude. JIM SCOTTI

[SPACEWATCH/UNIVERSITY OF ARIZONA]

comet's tail. At totality, Encke will be its normal self. As the Moon comes out of Earth's shadow, have a look every 10 to 15 minutes, and you will see the tail shrink dramatically.

By the 14th, the Moon rises late and Encke grazes Epsilon (ε) Cygni, the bright star on the left arm of the Northern Cross. Through the 16th, the comet will shine at 7th magnitude and will be nicely placed for wide-angle photos with the Veil Nebula. The following weekend (the 22nd), it will pierce the Coathanger.

Despite the oncoming moonlight, keep observing. Encke's bright core will be a nice sight though any backyard scope. On the 27th, the 6th-magnitude dirty snowball passes the beautiful star cluster NGC 6709, near where David Levy discovered Comet Levy-Rudenko in November 1984.

A comet in the wings

As if biding its time, a young upstart is ready to fill in for Comet Encke's fading nights.

COMET ENCKE POSITIONS

COMET 2P/ENCKE

{Date}	{R.A.}	{Dec.}
Nov. 1	23h35.4m	43°57'
Nov. 6	22h33.4m	42°19'
Nov. 11	21h26.5m	37°42'
Nov. 16	20h24.1m	30°14'
Nov. 21	19h31.7m	21°14'
Nov. 26	18h49.3m	12°15'
Dec. 1	18h14.9m	4°10'

Comet C/2002 T7 (LINEAR) will brighten gradually to 7th magnitude in February. It will burst into the morning sky in late April near 2nd magnitude.

Once the bright Moon leaves the evening sky this month, it will be easy to track C/2002 T7 across Perseus. At 9th magnitude, the fuzzy, roundish glow lies well within reach of a 4-inch scope from a rural site. Once you find it, bump up the power to 150x or so and examine the edges. You may need to have a dark cloth over your head to keep out stray light. One side will appear sharper, the edge facing the Sun, where the solar wind creates a bow wave in the dust and gas leaving the nucleus.

On Monday night, November 24/25, the comet passes across the face of NGC 1342, a sparkling star cluster visible in binoculars under dark skies. If our luck holds out against the typically cloudy weather of autumn, you should have plenty to write down in your observing log. ■





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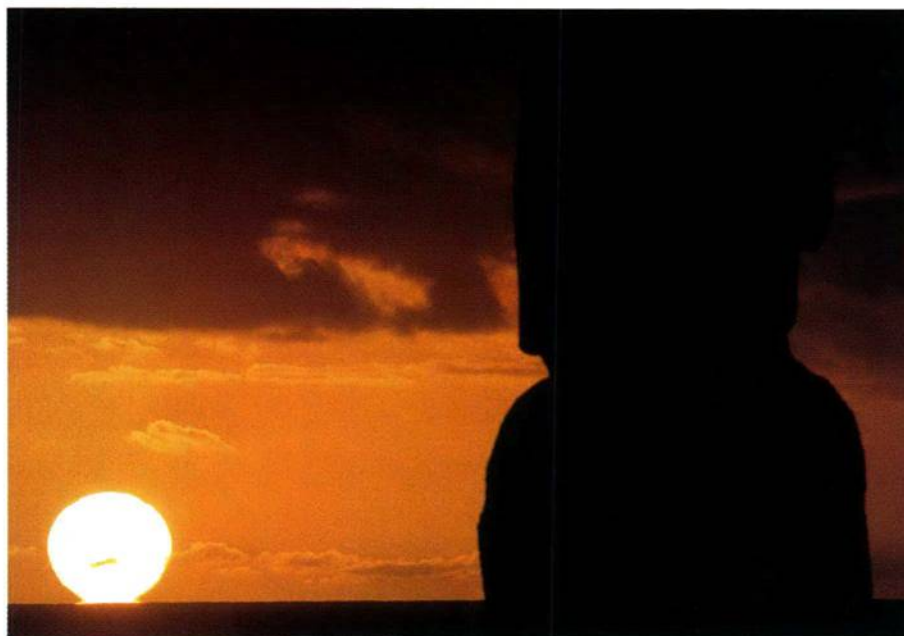
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ASK ASTRO

Ancient observations, dating rocks, seeing lunar landers

ANCIENT OBSERVATIONS

How could the ancient Greeks tell the days of equinoxes? If I remember correctly, on an equinox at their latitude, the day is approximately 12 hours and 6 minutes long, while the night is 11 hours and 54 minutes long. How did they solve the problem? — ANGELO ZOCCHI, SAN MACARIO, ITALY



THE SUN SETS into the ocean off Easter Island. Thousands of years ago, observers could deduce the dates of the equinoxes by accurately measuring the positions of sunrises and sunsets. OLIVIER STAIGER

The Greeks, as well as most other ancient peoples who had an abiding interest in the sky, used the astronomical seasons to mark the passage of time for their calendars. Typically they would create a “horizon calendar” based on the rising or setting points of the Sun.

Careful observation over a period of time allowed them to determine the northern and southern limits of these horizon points (the summer and winter solstice, respectively) as well as the geometric point halfway between them (the equinox, a point that the Sun’s disk crosses twice a year). Finding the equinox by applying geometry would have been comparatively

simple, especially for a civilization that has been credited with inventing the subject. They would mark the days when the center of the Sun’s disk crossed these points as the beginning of their astronomical seasons.

Many monuments that mark these days still exist. England’s Stonehenge, begun around 2800 B.C., is perhaps the most famous, with its alignment toward sunrise at the summer solstice. In the Western Hemisphere, El Castillo, which was the main pyramid-temple in the late Mayan/Toltec ceremonial center of Chichén-Itzá, served a similar function. On the equinoxes, the rising Sun casts a shadow that resembles a giant serpent undulating down

the side of the main stairway from the sanctuary at the structure’s summit.

Today, we measure the length of a day not from the rise and set of the Sun’s center, but from the first sliver of the Sun’s disk to break the horizon at sunrise to the last sliver vanishing at sunset. Because the Sun is not a mathematical point, the actual day of “equal night” (the literal meaning of equinox) does not fall on the equinox. In the Northern Hemisphere, day and night are equal a few days before the vernal equinox and a few days after the autumnal equinox.

Another effect — refraction — complicates things further. Earth’s atmosphere acts as a lens and makes the Sun appear to rise earlier and set later than it would without an atmosphere. The exact amount of refraction varies with meteorological conditions, but in general, it elevates the Sun by about a full solar diameter when it lies on the horizon.

The ability of ancient peoples to determine the cardinal directions via geometry may at first seem quite astounding. It’s not easy for us to determine what was passing through the mind of an educated person several thousand years ago, but the power to make observations and then perform a relatively simple calculation must have been an awesome concept. — GEOFF CHESTER, U.S. NAVAL OBSERVATORY

DATING ROCKS

I often read about geologic age measurements made using “the amount of naturally occurring radioactivity left in meteorites (or rocks).” How do these dating techniques work? — JACK WHITMAN, PHILADELPHIA, PENNSYLVANIA

The essential word here is radioactivity. Although the bulk of any material is made up of stable atoms, all materials contain

tiny amounts of radioactive atoms. Radioactive atoms decay in predictable ways at precise rates that can be tracked using their isotopes. (Isotopes of a given element have the same number of protons, so they are chemically identical, but they have different numbers of neutrons in their nuclei.)

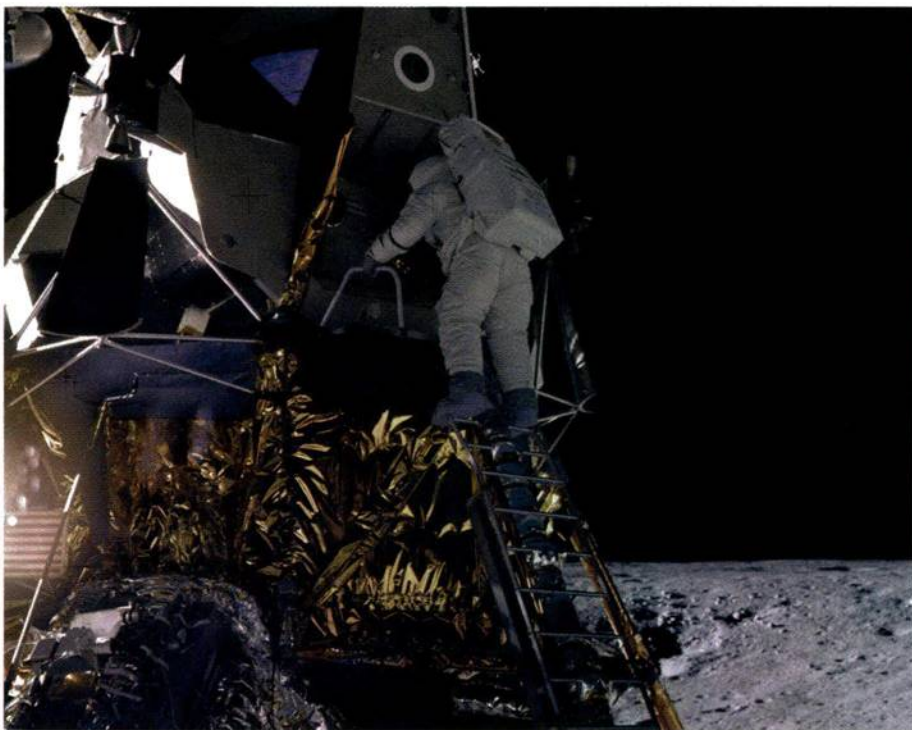
Take the element most often used for dating meteorites, rubidium. This is a relatively rare element, but its atomic size and chemistry are similar to geologically common elements like potassium and sodium. Small amounts of rubidium usually find their way into the crystal structure of minerals prevalent in meteorites.

About a quarter of all rubidium atoms are radioactive rubidium-87, which laboratory experiments show has a half-life of 47 billion years. An element's half-life is the time it takes for half of its original stock of radioactive atoms to decay.

The solar system is a lot younger than 47 billion years, so most of the original rubidium-87 still exists. Rubidium-87, which decays into strontium-86, is the only source of strontium-86 in the universe. When a meteorite forms, rubidium is locked into its crystal structure. As long as the rubidium and its strontium decay product don't go anywhere (and mineral crystals are great at holding onto atoms), you only need to measure the ratio of rubidium-87 to strontium-86 precisely. Because the half-life of rubidium-87 is well known, the ratio of these two isotopes will give you the date the meteorite formed.



MARTIAN METEORITE ALH84001, which formed 4.51 billion years ago, was ejected toward Earth 15 million years ago. Scientists derived these ages from the measured decay of radioactive elements in the meteorite. NASA



ASTRONAUT ALAN BEAN descends the ladder of the Apollo 12 lunar lander. The six landers from the Apollo missions are the largest pieces of hardware left on the Moon. NASA

The rubidium/strontium pair is just one of a number of isotopic systems used for dating ancient or relatively recent events. Other useful elements include potassium-40 (which has a half-life of 1.3 billion years), beryllium-10 (half-life of 1.5 million years), and carbon-14 (half-life of 5,700 years). — **DAN BRITT**, UNIVERSITY OF CENTRAL FLORIDA

SEEING LUNAR LANDERS

Can a backyard telescope show the lunar landers and other abandoned space vehicles on the Moon's surface? How about lunar mission debris still orbiting the Moon?

— **MARK DAVIS**, STUDIO CITY, CALIFORNIA

Unfortunately, no. All these objects are too small to be detected from Earth, even using a large telescope. And the Hubble Space Telescope can't do it either.

The largest pieces of hardware left on the Moon are the descent stages from the six Apollo lunar modules. A descent stage consists of a box about 9 feet high with

insectlike legs extending from it. Its extreme overall dimension (across the legs) is 31 feet, while the box that contained the fuel and descent engine is 14 feet across. Because the legs would be extraordinarily difficult to discern, the body of the descent stage would be the best bet to target through a telescope.

Regrettably, from Earth's distance of 238,900 miles, 14 feet spans an angular size of only 0.0023 arcsecond. This is well beyond what backyard telescopes can do — for them, half an arcsecond would count as extremely good resolution. Yet, 0.5 arcsecond covers more than half a mile on the Moon's surface.

New instruments, however, are beginning to approach the necessary resolution. When large telescopes work together as an interferometer, such as with the Very Large Telescope in Chile, they can discern such small angular sizes. But whether anyone would be willing to try to spot the hardware is another matter; large telescopes are oversubscribed already for use on regular research projects. — **ROBERT BURNHAM**, CONTRIBUTING EDITOR

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TV-85 , 3.35" f/7 apo	2080 ⁰⁰
TV-102 , 4" f/8.6 apo	2635 ⁰⁰
Renaissance 102 , 4" f/8.6 brass apo	3175 ⁰⁰
NP-101 , 4" f/5.4 apo	3595 ⁰⁰

All of the above scopes come without a mount, but with an eyepiece (except NP-101), enhanced aluminum or Everbrite star diagonal, tube ring for mounting, and case. Basic optical tubes, without accessories, are also available.

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TMB 130 130mm (5.1") f/6	5390 ⁰⁰
TMB 152 152mm (6") f/7.9	7590 ⁰⁰
TMB 175 175mm (7") f/8	12,990 ⁰⁰
TMB 203 203mm (8") f/9	24,990 ⁰⁰
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DEEP-SKY OBSERVING

One of our nearest galactic neighbors provides some tempting targets for amateur observers.

/// BY ALAN GOLDSTEIN

Exploring the Pinwheel

The Pinwheel Galaxy (M33) lies in the shadow of the proverbial Andromeda Galaxy (M31). Also known as NGC 598, the Pinwheel is a frequently observed object well placed in the evening sky during late summer and autumn. M33 takes up three times the area of the Full Moon and ranks as the third largest object in the Local

Group, our loose-knit neighborhood of galaxies. It lurks among the stars of Triangulum, approximately 3 million light-years away.

M33 is one of the best northern galaxies to view with amateur telescopes in terms of resolving nebulae and star clouds. Several of these objects are bright enough to merit individual NGC or IC numbers. A good observing target for amateurs, the Pinwheel Galaxy contains many deep-sky objects that can be seen through medium-sized telescopes.

Sizing up M33

Located 4° west-northwest of Alpha (α) Trianguli, M33 appears as a ghostly cloud among the stars. Although M33 glows with one-eighth the brightness of M31, it's detected easily through the smallest binoculars and with the naked eye under dark skies. For several reasons, this galaxy is more difficult to see than M31.

The Pinwheel Galaxy is 300,000 light-years farther from Earth than the Andromeda Galaxy. It's also much less massive, containing about 10 billion stars, while our own galaxy and M31 each contain more than 200 billion. We view the Pinwheel Galaxy tilted only 33° to our line of sight. M31, however, is inclined at about 78°, and its light is intensified because we view it edge-on, through its thick spiral



NGC 604 is the brightest of the objects associated with M33. This region, located in the galaxy's spiral arm, is fertile for star birth. Although such nebulae are common in galaxies, this one, nearly 1,500 light-years across, is the second largest known. ROBERT GENDLER

arms. Finally, M33 spans approximately 50,000 light-years compared to M31's 100,000 light-year diameter.

Some astronomers consider M33 to be a distant part of the M31 subgroup, as the galaxies lie some 700,000 light-years apart. The largest emission nebula in the Local Group — NGC 604 — inhabits an outer spiral arm of M33. The large star clouds in many of the arms comprise a conspicuous part of the galaxy's structure.

Inside the spiral

M33 has a very loose spiral structure. It has two dominant arms: One contains IC 142, IC 143, and NGC 604, and the opposite contains IC 139, IC 140, IC 136, and

NGC 585. Between them lie two diffuse arms: One contains two large star clouds, and the opposite contains NGC 592 and possibly NGC 595. Numerous "spurs" or short arms emanate and lie between the four primary spiral arms. It's difficult to tell where one arm ends and another begins, but eight or nine distinct concentrations or "arms" exist in the outer perimeter. M33 indeed offers a celestial "pinwheel" — one that has been spinning for hundreds of millions of years.

Star clouds and emission nebulae (HII regions) define the structure of M33, as in most spiral galaxies. The proximity of M33 to the Milky Way allows its structure to be visible in moderate scopes. In 1849, William Parsons, third earl of Rosse, observed and sketched the sweeping spiral structure of M33 with his 72-inch speculum mirror at Birr Castle, Ireland. This was one of the first galaxies to reveal such a structure. The same spiral structure is visible today with a 6-inch telescope under good skies. The key is to observe with low magnification. A 12- to 20-inch telescope using magnifications under 100x will show overwhelming detail. Higher magnification allows observation of individual or groups of objects.

Star clusters

While M33's spiral structure was discovered in the mid 19th century, the brightest object embedded in it was recorded decades earlier. Now known as NGC 604, John Herschel cataloged it as H III.150. A giant gas cloud 1,500 light-years in diameter located inside a cluster of 200 massive stars, this cloud of hydrogen is one of the largest known in the heavens — second only to 30 Doradus in the Large Magellanic Cloud (LMC). It will spawn thousands of stars in the future, creating a star cloud that will dominate the spiral arms of M33 for a billion years. NGC 604 is the largest of the

Alan Goldstein is founder and coordinator of the National Deep Sky Observers Society.

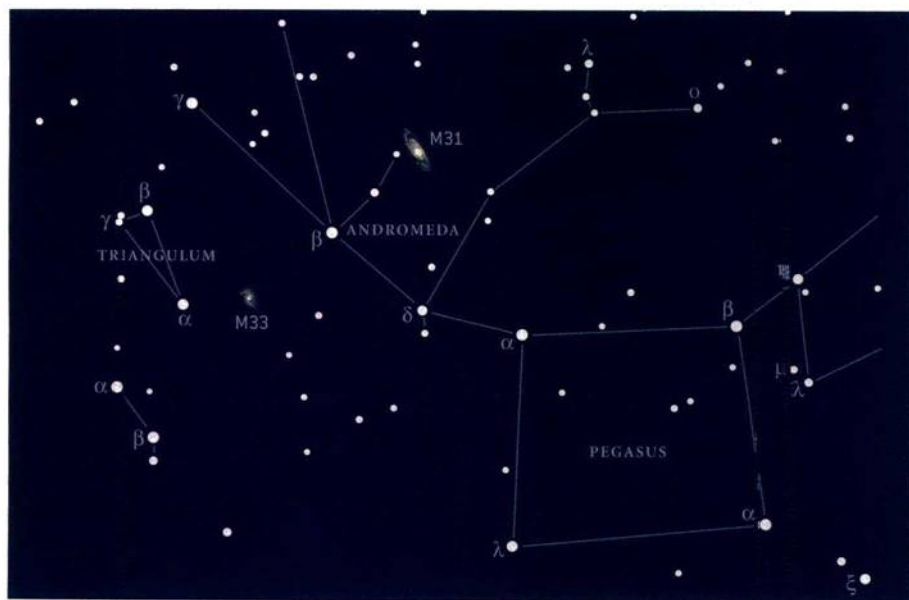


THE PINWHEEL GALAXY (M33) in Triangulum was imaged with a 12.5-inch Optical Guidance Systems Ritchey-Chrétien telescope at f/6 and an SBIG ST10 CCD camera. This is a two-image mosaic, each an LRGB with exposure times of 60, 10, 10, and 10 minutes, respectively. ROBERT GENDLER

1,272 emission objects recently cataloged by University of Washington astronomer Paul Hodge and associates in 1999.

Along with the huge number of emission objects in the Pinwheel Galaxy, 10 HII regions are visible through modest telescopes. Using a star chart and a medium-sized scope, it is possible to locate IC 142 and IC 143 lying west of NGC 604 on the same spiral arm. NGC 595 is a peculiar HII region positioned at the edge of a large neutral hydrogen cloud located between two of the galaxy's spiral arms. NGC 592 lies on another, less conspicuous arm more or less in line with IC 142 and NGC 595. NGC 588 lies west of NGC 592, in line with the nucleus. IC 131, 132, and 133 are aligned north-south in the northwest part of M33. IC 131 is the most condensed, and IC 133 is the largest. IC 135 lies in the arm below NGC 604, equidistant from the nucleus on the other side of M33.

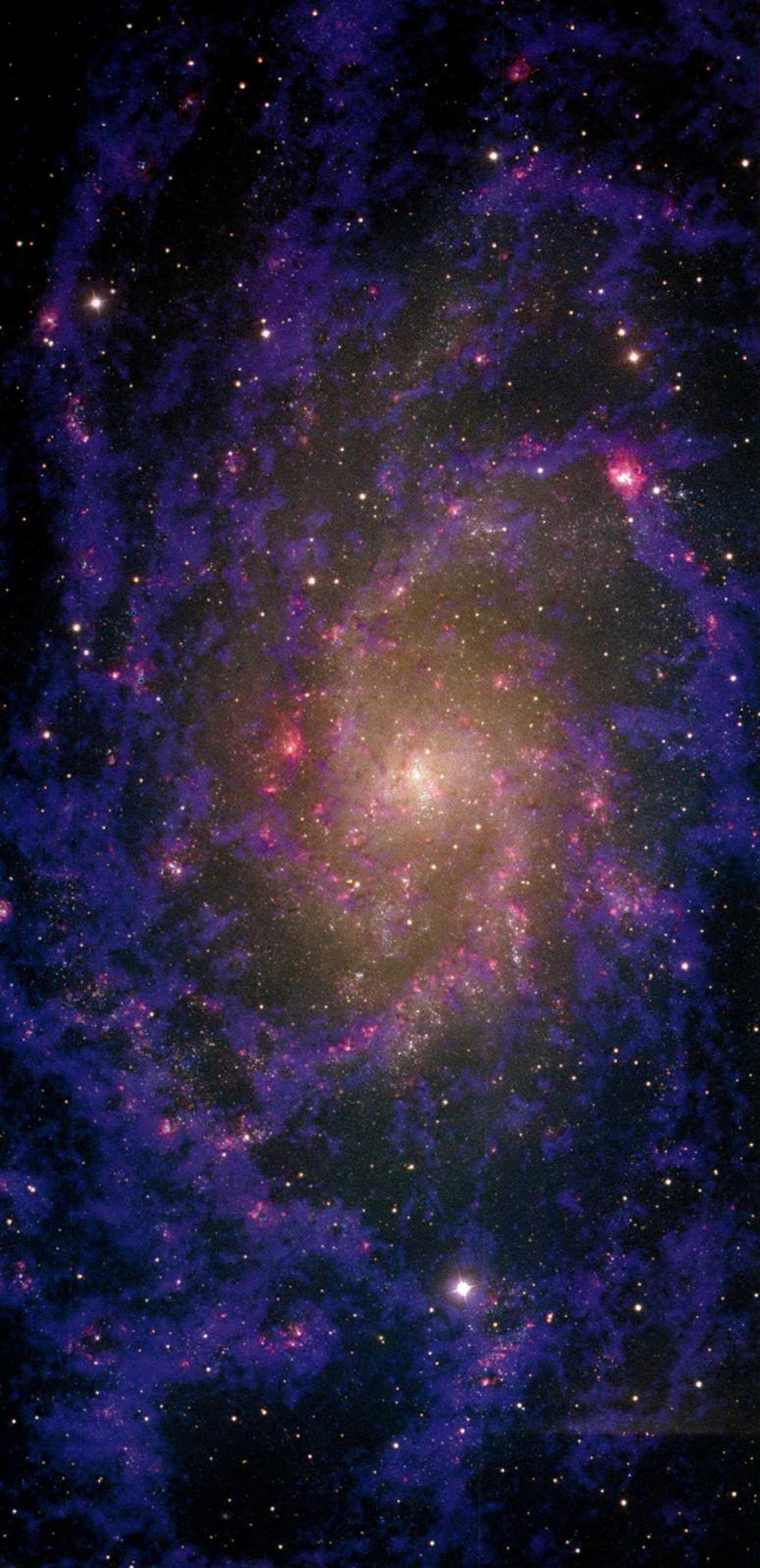
Both galactic (open) and globular clusters exist in M33, as well as "blue globulars," compact clusters that superficially resemble regular globulars, but whose stars are much bluer. Scientists also have located blue glob-



ulars in the Large Magellanic Cloud. Star clusters in the M33 system range from very old (more than 10 billion years) to very young (less than 100 million years).

While open clusters within the Pinwheel are much too faint to be observed with amateur telescopes, several globular clus-

ters may be seen with 20-inch or larger apertures. A galaxy with a small mass like M33 is expected to have a small contingent of globulars. Only about 20 have been found. By comparison, the Milky Way has approximately 160, and M31 contains an estimated 400 clusters. The



average absolute magnitude of M33 globulars is -7 , almost a full magnitude dimmer than those in the Andromeda Galaxy. The brightest globular cluster in M33 is designated C 39. It is magnitude 15.9 and lies about $22'$ southeast of M33's nucleus, outside the main structure of the galaxy. Other globular clusters are 17th magnitude and fainter.

Associations, SNRs, and nebulae

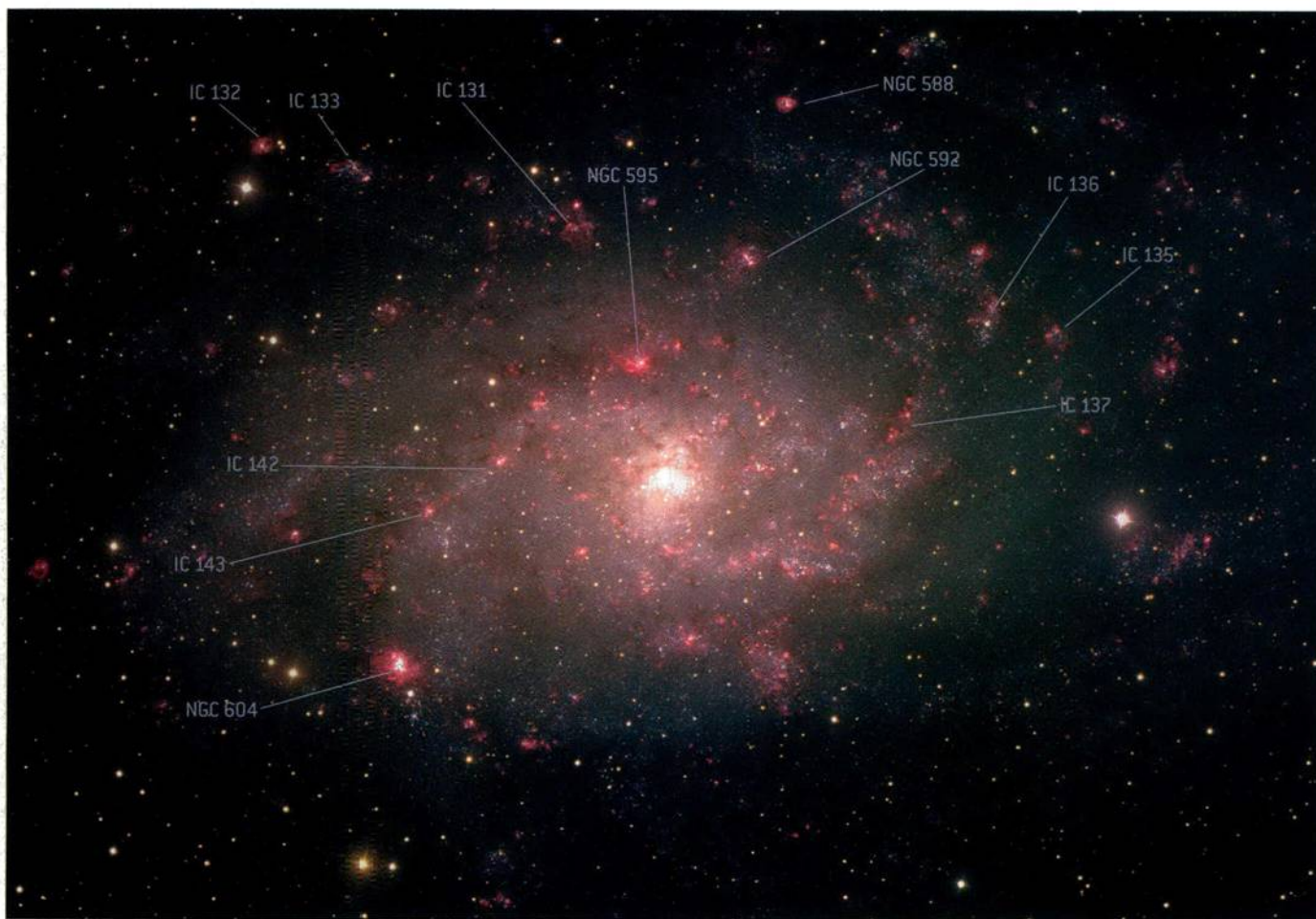
Brighter and larger than M33's clusters are its stellar associations, larger clumps of young stars that trace out the spiral structure. Many associations have smaller HII regions embedded in them. The brightest blue stars in M33's associations have absolute magnitudes of -9.4 , and the brightest red stars are -8 , comparable to the most luminous in our galaxy. Among the easiest associations to see are IC 136, IC 137, IC 139, and IC 140. IC 136 is located south of IC 135 (southwest of NGC 604 on the eastern side of M33). IC 137, IC 139, and IC 140 are located in the main arm below the nucleus.

As of this writing, 98 supernova remnants (SNRs) have been identified in M33. This compares with about 200 SNRs known in M31 and 32 in the LMC. A study by Shawn Gordon and Robert Kirschner in 1998 obtained diameters of SNRs in M33 between 35 and 400 light-years. (At the distance of M33, $1.25'' = 1$ light-year. The Crab Nebula, therefore, would have a diameter of only $0.9''$ at M33's distance.) As a result of this study and others, astronomers estimate a supernova occurs in M33 every 360 years.

Dark nebulae lie scattered throughout M33. Unlike M31, which is highly inclined and shows dark lanes clearly in small telescopes, M33's orientation is closer to face-on, making dust clouds more difficult to observe. They are most apparent in densely populated areas of stars.

A MULTIWAVELENGTH IMAGE of the Pinwheel Galaxy was created by combining optical data from the National Science Foundation's (NSF) 0.9-meter telescope on Kitt Peak in Arizona with radio data from the NSF's Very Large Array telescope in New Mexico and the Westerbork Synthesis Radio Telescope in the Netherlands. The optical data in this image show stars and reddish star-forming regions throughout the galaxy's spiral arms. The radio data reveal cool hydrogen within the galaxy.

NICHOLE KING (STScI) ET AL., MAYALL TELESCOPE/KPNO/NOAO/NSF



USE THIS FINDER CHART to identify objects in M33's area. MAIN IMAGE: T. A. RECTOR (NRAO/AUI/NSF AND NOAO/AURA/NSF) AND M. HANNA (NOAO/AURA/NSF). OVERLAY: ASTRONOMY, KELLIE JAEGER

The core

One feature M33 lacks is a distinct nuclear bulge, which is typical of low mass spiral galaxies like M33. The central core region measures only between 1.5' and 3' in diameter, or roughly 2 light-years. Only M32 and the Milky Way have smaller cores. Any black hole lurking in the heart of M33 would have a very low mass.

Into the future

The Pinwheel Galaxy has been the subject of intensive research for more than a century. Each year, astronomers publish numerous studies of this galaxy, scrutinizing its every aspect across the electromagnetic spectrum. Although a deeper understanding of M33 now exists, many new questions arise. In the future, exploration of M33 with large telescopes equipped with adaptive optics, as well as by the Hubble Space Telescope, will shed more light on our corner of the universe. ■

/// NGC and IC objects in M33

OBJECT	TYPE	LOCATION (2000.0)	MAG. (b=blue, v=visual)	SIZE
IC 131	HII	01h33m12s 30°45'	12.5b	0.4'
IC 132	HII	01h33m18s 30°52'	—	0.2'
IC 133	HII	01h33m18s 30°53'	12.2b	0.4'
IC 135	HII	01h34m12s 30°37'	—	0.6'
IC 136	Assoc.	01h34m12s 30°34'	11.0b	1.8' by 1'
IC 137	Assoc.	01h33m36s 30°31'	—	0.4'
IC 139	Assoc.	01h33m42s 30°34'	13.1b	—
IC 140	Assoc.	01h33m42s 30°33'	—	—
IC 142	HII	01h33m54s 30°45'	11.3b, 14.2v	0.5'
IC 143	HII	01h34m06s 30°47'	11.4b	0.5'
NGC 588	HII	01h32m45s 30°39'	11.5b	1.5' by 0.7'
NGC 592	Assoc./HII	01h33m12s 30°39'	13.0b	0.8' by 0.7'
NGC 595	HII	01h33m34s 30°42'	13.1b	1' by 1'
NGC 604	HII	01h34m33s 30°47'	11.5b	1.5' by 1.5'

Object: Designation in Index Catalog (IC) or New General Catalog (NGC). **Type:** HII = Ionized atomic hydrogen cloud, **Assoc.** = Association (loose cluster of stars). **Location:** Right ascension and declination. **Mag.:** Magnitude. **Size:** Size in arcminutes.



To learn more about the Pinwheel Galaxy, visit www.astronomy.com/toc



SOLAR SYSTEM OBSERVING

This month, two 8th-magnitude stars will flicker on and off through Saturn's Cassini Division. /// BY ALISTER LING

Diamonds in the rings

Flash back to a sultry summer evening in 1989, when the Ringed Planet passed in front of the bright star 28 Sagittarii. The 5th-magnitude star fluctuated wildly in brightness when it emerged from behind the cloak of the B ring into the gauzy C (or Crepe) ring, prompting ecstatic shouts from observers like me.

Such obscurations of one celestial body by another, called occultations, are not only thrilling sights, but they also can net important discoveries. Saturn's rings contain "ringlets" of ice-covered rocks that range in size from specks to free-floating mountains. By observing how a star's light changes during an occultation, astronomers can plot the gaps between ringlets, along with the ringlets' width and density.

This month, Saturn will occult two 8th-magnitude stars. The show won't be as spectacular as the brighter 28 Sgr event, but these stars, which are about as bright as 8.3-magnitude Titan, Saturn's largest moon, should put on memorable displays.

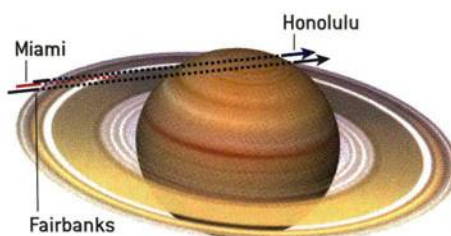
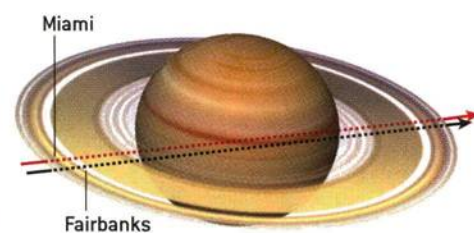
Shortly after 05:20 UT on November 15 (12:20 A.M. EST, 9:20 P.M. PST on November 14), an 8.8-magnitude star called SAO 78867 will sit poised on the edge of the



28 SAGITTARII, a 5th-magnitude star, shone from inside Saturn's rings on July 3, 1989. This month, two 8th-magnitude stars will do the same. TOM OSYPOWSKI

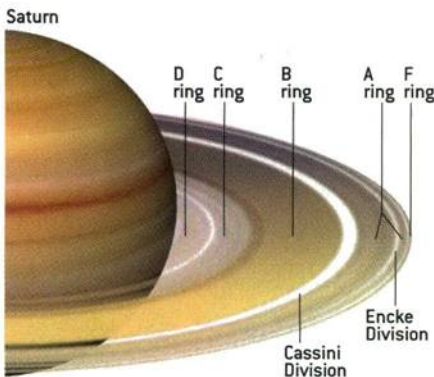
rings. Like stars losing a daytime battle with the Sun, this star won't be seen shining through the bright A or B rings.

The best action will take place in the translucent Crepe ring, although observers



ON NOVEMBER 14/15, (top) Saturn will float across an 8.8-magnitude star, which should flicker on and off on both sides of the planet. ASTRONOMY: ROEN KELLY

ON NOVEMBER 24/25, (bottom) our line of sight will allow us to see an 8.5-magnitude star wink on and off on only one side of the planet. But there's a small chance the star will shine through the B ring for three minutes in Saturn's shadow. ASTRONOMY: ROEN KELLY



SATURN'S RINGS vary in size, density, and brightness. Observers can detect these differences by noting how the obscured star's light changes as the Ringed Planet passes in front of it. *ASTRONOMY: ROEN KELLY*

would do well to watch the main gap, called the Cassini Division, as well. The Voyager 1 and 2 spacecraft, which visited the planet in 1980 and 1981, respectively, proved this gap is not empty. It's filled with faint ringlets, and each will make the star flutter. Also, keep your eyes peeled just before and after the star leaves the outer edge of the ring system — the gossamer, braided F ring should induce a noticeable flicker even if the ringlet itself is invisible. Large scopes may show the star reappearing in the A ring's tiny Encke Division.

This same star will be occulted also by Saturn's moon Titan around 00:11 UT on November 14, but this event will be visible only from southern Africa. The same day, North American observers with large telescopes may be able to catch an occultation of the 10th-magnitude star TYC 1343-01865 by Titan at 06:57 UT.

The second event, on November 24/25, is an occultation of a similarly bright 8.5-magnitude star called SAO 78832. Because our line of sight won't be as good as it was in the first event, Saturn will appear to slide across at an angle, resulting in an occultation by only one side of the rings before the star emerges from behind Saturn's south polar area. Observers west of the Great Lakes also may be able to make a very unusual observation: Just before the star disappears behind the planet's cloud tops, it may flicker into view where Saturn is casting a shadow onto the B ring (this event is

Alister Ling is a meteorologist with Environment Canada and co-writes *Astronomy's* regular feature "The Sky This Month."

/// DETAILS OF THE EVENT ON NOVEMBER 14/15, 2003

	1st D	Cassini	Cr1st	Cr1end
Fairbanks	5:33	6:00	6:48	7:07 occult
New York	5:27	5:55	6:39	7:04
Miami	5:26	5:50	6:37	7:01 then occult 7:05
Los Angeles	5:29	5:57	6:43	7:04 occult
London	5:20	5:47	6:35	6:58 (may be lost by 6:20 in twilight)
Honolulu	5:30	5:58	6:46	7:10 occult

	Reapp	Cr2st	Cr2end	Cassini	End
Fairbanks	10:37	10:55	11:20	12:02	12:34
New York	10:31	10:45	11:11	11:52	12:22
Miami	10:31	10:44	11:08	11:50	12:20
Los Angeles	10:37	10:49	11:14	11:56	12:26
Honolulu	10:43	10:56	11:20	12:00	12:30

All times are UT; EST is 5 hours earlier, PST 8 hours earlier. **1st D:** First disappearance. **Cassini:** Estimated start of the Cassini events, which will last three to four minutes. **Cr1st** and **Cr1end:** Start and end of the first Crepe ring events; occult indicates that the star is occulted by Saturn's disk. **Reapp:** Reappearance. **Cr2st** and **Cr2end:** Start and end of the last Crepe ring events.

/// DETAILS OF THE EVENT ON NOVEMBER 24/25, 2003

	1st D	Cassini	Bshade	Reapp
Fairbanks	10:48	11:21	12:19	14:01
New York	10:42	11:18		
Miami	10:45	11:23		
Los Angeles	10:49	11:25	12:28	13:53
Honolulu	11:00	11:44	12:28	13:51

Areas east of the Central Plains face twilight. New York and Miami may not see the Cassini events as the sky there brightens by 11:05. **Bshade:** Slight chance of observing the star for about three minutes while it is behind the B ring but in the planet's shadow.

uncertain because the star's light may not be able to penetrate the dense ring).

Observing tips and tricks

A motor drive is best to keep Saturn centered in the field, but a wide-field, high-power eyepiece on a smooth, hand-pushed mount is a reasonable substitute. If you're new at this, practice with your setup for a few nights beforehand.

Make sure you leave an hour for your scope and optics to cool to the ambient air temperature. It's tough enough suffering through upper-atmospheric turbulence — you don't want heat from your own telescope to contribute to a bad view. Find a spot away from rooftops and other surfaces that quickly release heat absorbed during the day.

Don't forget which way is up! Use the diagram showing the positions of the

brighter moons as a reference. A refractor or Schmidt-Cassegrain with a star diagonal will flip images left to right. You might want to scan the diagram into your computer and flip it with an imaging program.

Use as high a magnification as the turbulent air permits. You'll want to separate the star from the rings and Saturn's cloud-tops when it gets near them.

Be sure to take advantage of this month's double delight — occultations of stars by Saturn are rare, especially when you consider the vagaries of weather, time of day, and distance above the horizon. The next such event for a star brighter than 6th magnitude isn't until April 7, 2032. These diamond rings are precious indeed, but enjoying them doesn't cost a cent. ■



Learn how to make a light curve of these occultations at www.astronomy.com/toc

ASTROPHOTOGRAPHY

A pair of world-class astrophotographers takes us through a night on their favorite mountain. /// TEXT AND PHOTOS BY BOB AND JANICE FERA



A night with the Feras

New Moon is an exciting time for us. For nearly a month, we anticipate setting up our telescope, choosing targets, and creating images of celestial objects. Unfortunately, our suburban Los Angeles home suffers from a high level of light pollution. To pursue our passion for astrophotography, we drive about 90 miles north to

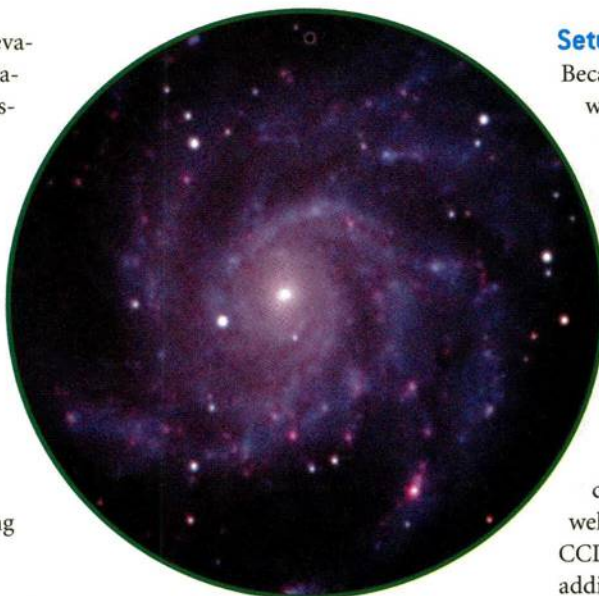
Mt. Pinos, part of the Transverse Mountain Range. Mt. Pinos's high elevation (8,831 feet), good seeing, and relatively dark skies make it a popular destination for amateur astronomers in southern California.

During the summer, when nighttime temperatures stay well above freezing, three hundred or more enthusiasts may spend a moonless Saturday night in the Chula Vista parking area near the summit. Other seasons bring colder temperatures with the possibility of ice and snow, and far fewer amateurs are in attendance. Mt. Pinos is where we've learned almost everything we know about taking astronomical images, thanks to the many great astrophotographers who have frequented this famous dark-sky site.

Lessons learned

One of the first lessons we learned was the importance of a good mount. A quality OTA (optical tube assembly) is only half of the system — if you put it on a bad mount, you won't be happy with the outcome. As a result, we've been using an Astro-Physics 1200 equatorial mount on a heavy-duty, homemade tripod for about nine years. Lugging around this much equipment was a chore, and it led to lesson number two: We

Bob and Janice Fera live in California and continue to image during each New Moon on Mt. Pinos.



SPIRAL GALAXY M101 IN URSA MAJOR

(Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypered Kodak Pro 400 PPF film, 90-, 90-, and 120-minute exposures, taken from Sun Glow Ranch, Arizona)

store the mount, tripod, and most of our other non-optical-tube equipment in a small utility trailer that's ready to go when dark skies call.

Evolution

After many happy years of shooting with our trusty 11-inch f/10 Celestron SCT, we've recently acquired a 12.5-inch f/9 Ritchey-Chrétien Cassegrain built by Parallax Instruments and an 8-inch f/4.5

Newtonian with Discovery optics built by Tony Hallas.

For many years, our pictures were shot with 35mm film, most recently Kodak Royal Gold 200 and Fuji Super HQ 100. We use a Canon F1 body as our main camera. We've just begun experimenting with an SBIG ST-10XE CCD camera, which we're very excited about.

Setup

Because the parking lot is often crowded, we always arrive well before dark to stake out a spot and set up all the gear. The site has no facilities except a couple Porta-Potties, so we have to be completely self-sufficient. Because the mount breaks down into manageable pieces, setup takes about an hour and can be accomplished by one person. A little help is always appreciated hoisting the 60-pound Cassegrain into its mounting rings, though. Once the complete rig is assembled, it weighs well over 300 pounds. As we delve into CCD imaging, we've had to pick up some additional equipment — four deep-cycle marine batteries to power the camera and computer, in addition to the scope.

Dusk is a special time in the Mt. Pinos parking lot. The temperature drops rapidly, and the energy and anticipation can be felt amidst the smells of dinners cooking and the buzz of a few hundred astronomers eager for nightfall.

As darkness falls, we accurately polar align the telescope using the drift alignment method. Then, we're ready to shoot. Unlike some of our compatriots, we tend to be quite disorganized when it comes to choosing imaging targets. Many times, we'll just look up at the sky while polar aligning and decide then and there what the night's targets will be.



THE HORSEHEAD NEBULA (B33) IN ORION [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, Astro-Physics 1200 mount, SBIG ST4 CCD camera autoguider, hypered Kodak Pro 400 PPF film, 90-, 90-, and 100-minute exposures, taken from Mt. Pinos, California]



THE BLACK EYE GALAXY (M64) IN COMA BERENICES [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, SBIG ST4 CCD camera autoguider, hypered Fuji Super HQ 100 film, 120- and 180-minute exposures, taken from Mt. Pinos, California]

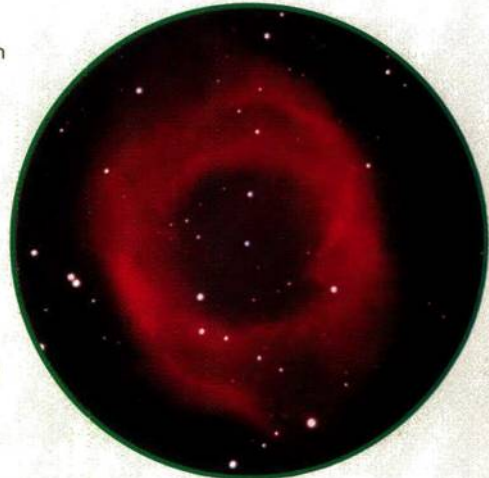


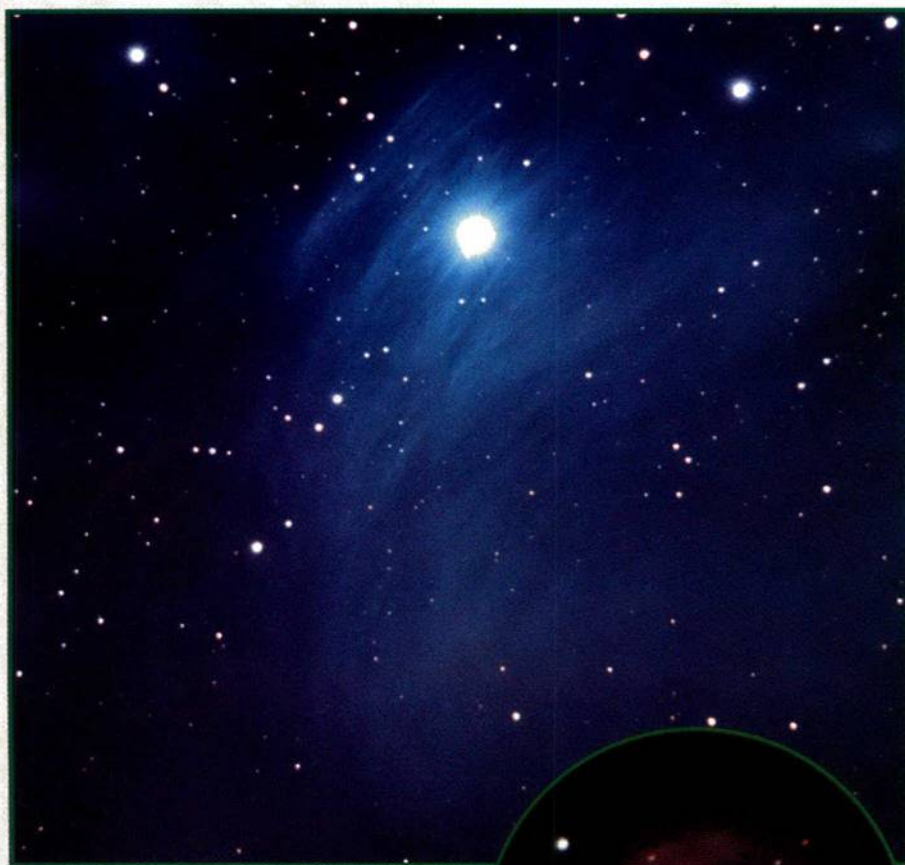
THE BUBBLE NEBULA (NGC 7635) IN CASSIOPEIA [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypered Kodak Pro 400 PPF film, 90-, 90-, and 120-minute exposures from Mt. Pinos, California]



THE DUMBBELL NEBULA (M27) IN VULPECULA, (LEFT) [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, Astro-Physics 1200 mount, SBIG ST4 CCD camera used as an autoguider, hypered Kodak Pro 400 PPF film, three 45-minute exposures, taken from Mt. Pinos, California]

THE HELIX NEBULA (NGC 7293) IN AQUARIUS, (RIGHT) [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypered Kodak PJM film, two 90-minute exposures, taken from Sun Glow Ranch, Arizona]





NEBULOSITY SURROUNDING THE STAR MEROPS IN THE PLEIADES (M45)

[Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypersensitized Kodak Pro 400 PPF film, two 60-minute exposures, taken from Mt. Pinos, California]



Imaging

Once we've decided on an object, we frame it in the viewfinder of the Canon F1. This can be a challenge because some faint objects can't be seen through the camera. If this is the case, we'll search for a photograph of the object to help identify surrounding star patterns. When you're about to commit several hours to an exposure, you want to be sure the telescope is actually pointing at the object.

Next, we locate a guide star in the Lumicon off-axis guider and center it using an illuminated reticle eyepiece. We've learned to do this carefully so as not to affect the framing of the target. At this point, we securely tighten the knobs that hold the off-axis guider to make sure nothing moves during the shot.

Now that the object is framed and the guide star centered, we move the telescope to a nearby bright star to focus. Before moving from our target, we take advantage of a feature in the Astro-Physics

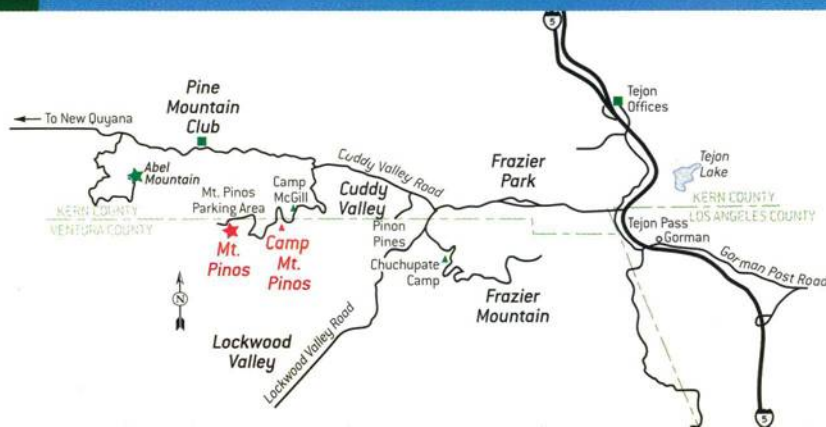
PLANETARY NEBULA NGC 246 IN CETUS [Celestron 11-inch Schmidt-Cassegrain telescope at f/10, Kodak Pro 400 PPF film, two 75-minute exposures, taken from Mt. Pinos, California]

software that re-synchronizes the mount on the object so we'll be able to return to it after focusing. We use the Spectra Sure-Sharp knife-edge system to focus. When

we're done focusing, we slew the telescope back to the target, which, thanks to the goto mount, is still perfectly framed.

The next step is to remove the illuminated reticle eyepiece from the off-axis guider and replace it with the SBIG ST-4 autoguider. After setting the autoguider's parameters and calibrating it, at last we're ready to start our shot. We say "at last" because it can take an hour to set up a photograph properly. Exposures last 30 minutes

/// FINDING MT. PINOS





NORTH AMERICAN AND PELICAN NEBULAE IN CYGNUS (Canon 200mm lens at f/4, hypered Kodak PJM film, two 150-minute exposures, taken from Sun Glow Ranch, Arizona)

to 3 hours, depending on the scope and the object. We take at least two (more if time permits) exposures that we later combine digitally. By using multiple exposures, we can enhance an object's faint details more than is possible with a single exposure.

During a shot, when we can tear ourselves away from staring at autoguider readouts (a bad habit!), we take time to chat with friends. We also look through nearby scopes, stare at the sky, and even take an occasional nap.

In the summer, when nights are short, we spend two nights on the mountain. We go to bed at dawn and spend the following day snoozing and discussing the previous night's adventures with friends. And we wait for darkness to return. ■



To learn more about astrophotography, visit www.astronomy.com/toc



GLOBULAR CLUSTER M2 IN AQUARIUS (Celestron 11-inch Schmidt-Cassegrain telescope at f/10, hypered Kodak Pro 400 PPF film, two 30-minute exposures, taken from Mt. Pinos, California)



THE VEIL NEBULA AND 52 CYGNI (Celestron 11-inch Schmidt-Cassegrain telescope at f/10, Kodak PJM film, three 90-minute exposures, taken from Mt. Pinos, California)



THE REGION OF ANTARES AND RHO OPHIUCHI (Nikon 105mm lens at f/4, unhypered Kodak PJM film, 25- and 35-minute exposures, taken from Sun Glow Ranch, Arizona)



EQUIPMENT REVIEW

Trying to find that perfect holiday gift? *Astronomy* reviews 25 great telescopes that are proven performers. /// BY MICHAEL E. BAKICH

SUPER scope buyer's guide

I love to observe. Planets, star clusters, galaxies, the Sun — it really doesn't matter. Any object you call "celestial" evokes a thrill within me. ☾ Over the years, I've looked through thousands of telescopes. As you might guess, the most memorable views were through those of the

highest quality. First and foremost, this means optical quality. But there's more. I've seen that mechanical excellence, ease of use, size, accuracy of drive, and other factors are each highly important.

So when asked to compile my "favorite 25" I said, "No problem." And guess what? It really wasn't a problem.

The list is divided into three groups: refractors, reflectors, and compound telescopes. The first group, refractors, also includes a dedicated solar telescope comprised of a hydrogen-alpha filter permanently mounted on a refractor.

Within each group, telescopes are arranged alphabetically by brand name.

Their apertures range from 2.7 inches to 20 inches, and there's also a wide range in price. In all cases, however, the telescopes listed here are not toys — at least, not *children's* toys. Each is a quality instrument that will support many years of sky exploration, and each gets my wholehearted recommendation.

REFRACTORS

Astro-Physics 130mm Starfire EDT

The first telescope on the list is a terrific example of a "color-free" refractor, known as an apochromat. With more than five inches of clear aperture and a focal length

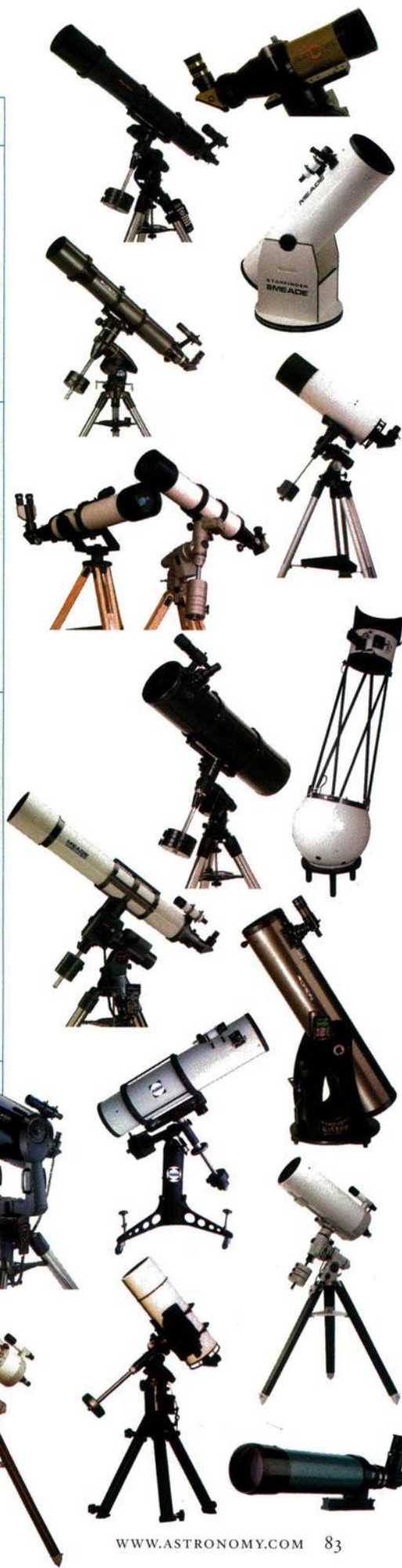


FRANK ZULLO

/// Super scopes

	MANUFACTURER / MODEL	APERTURE	f/RATIO	MOUNT / TRIPOD (INCLUDED?)	PRICE
Refractors	Astro-Physics 130mm Starfire EDT	5 inches	f/8.35	No	\$4,740
	Celestron C6-R	6 inches	f/8	Yes	\$799
	Coronado MaxScope 70	2.7 inches	f/5.7	No	\$3,348
	Meade 152ED	6 inches	f/9	Yes	\$4,799
	Orion SkyView Pro 120	4.7 inches	f/8.3	Yes	\$550
	Tele Vue Ranger	2.7 inches	f/6.8	No	\$570
	Tele Vue NP 127	5 inches	f/5.2	No	\$6,000
Reflectors	Celestron C8-N	8 inches	f/5	Yes	\$649
	Mag 1 Instruments PortaBall 8	8 inches	f/6	Yes	\$2,250
	Meade 12.5-inch Starfinder Dobsonian	12.5 inches	f/4.8	Yes	\$1,245
	Orion SkyQuest XT8	8 inches	f/5.9	Yes	\$350
	Orion StarBlast	4.5 inches	f/4	Mount	\$150
	Parks Optical Superior 10-inch	10 inches	f/5	Yes	\$3,500
	Starmaster 14.5-inch	14.5 inches	f/4.3	Yes	\$4,795
	Starmaster 20-inch	20 inches	f/4.3	Yes	\$7,395
Compound Telescopes	Celestron CGE-1100	11 inches	f/10	Yes	\$4,149
	Celestron NexStar 8i	8 inches	f/10	Mount	\$1,149
	ITE Telescopes Intes MK67	6 inches	f/12.5	No	\$1,135
	Meade ETX-90EC	3.5 inches	f/12	Mount	\$495
	Meade 12-inch LX200 GPS	12 inches	f/10	Yes	\$2,995
	Questar 3.5-inch Standard	3.5 inches	f/14.4	Mount	\$4,050
	Takahashi CN-212	8 inches	f/12.4	Yes	\$10,585
	Takahashi Mewlon 250	10 inches	f/12	Yes	\$11,995
	TEC 6	6 inches	f/12	No	\$1,950
	TEC MC200	8 inches	f/15.5	No	\$4,900

Prices shown are typical retail



of nearly 1,100mm, the f/8.35 Starfire EDT makes a superb telescope for planetary observations. It employs a triplet objective (three lenses) to correct for optical defects.

A 2.7-inch-diameter focuser comes as standard equipment, but both 1¼" and 2"

Celestron C6-R

The new C6-R, a 6-inch f/8 refractor from Celestron, is an affordable entry into the "medium large" refractor market. Celestron held the cost of the C6-R down by using a two lens achromatic objective

ing wavelength (656.28 nanometers) and see prominences, flares, and the chromosphere, the Sun's lower atmosphere. This is observing at its best because changes can occur on the Sun over a span of minutes, rather than hours or days.

The Starfire EDT employs a triplet objective (three lenses) to correct for optical defects, most notably chromatic aberration.

adapters are included. A 2.5-inch-long focuser extension also is included for observers who want to view straight through the telescope (without using the diagonal). In addition to visual observing, astrophotography is a joy through this scope. For a 35mm camera shooting at prime focus, the field of view measures a wide 1.3° by 1.8°.

A mount and tripod for this telescope must be purchased separately. Also, the waiting list for these limited-run telescopes is lengthy. Don't expect to have this scope in your hands by Christmas 2003 (or perhaps even 2004).

Michael E. Bakich is associate editor of *Astronomy*.

rather than something with more elements or with exotic glass.

Included with the C6-R is Celestron's popular CG-5 German equatorial mount and a new, heavy-duty tripod designed to improve image stability. With 2-inch tubular steel legs and a total weight of 57 pounds, this scope will provide a good base from which to observe. Observers interested in astrophotography also should buy a computerized, go-to motor drive for the CG-5 mount.

Coronado MaxScope 70

The MaxScope 70 is not just a solar telescope — it's a hydrogen-alpha solar telescope. With it, you can observe the Sun at one astrophysically significant and reveal-

The MaxScope 70 is sold without a mounting or tripod. It is, however, easily transported and very rugged. As an added plus, the telescope is beautiful to look at — but it's even better to look *through*. The image is crisp and relatively bright, especially considering how little of the Sun's light actually strikes your eye.

Safety is a concern with solar telescopes of any type. The MaxScope 70's front filter is attached permanently at the factory. In fact, the folks at Coronado like to boast that a teenager with a set of wrenches could not remove it. Now that's safe!

Meade 152ED

Meade has developed a new line of apochromatic refractors well worth the



consideration of backyard observers. The 152ED is Meade's 6-inch $f/9$ model. Other telescopes in this line (all $f/9$) are the 102ED (4-inch), 127ED (5-inch), and 178ED (7-inch). In each case, ED stands for "extra-low dispersion," which refers to the type of glass used in the second element of the objective lens. Using a two-element lens system sets this telescope apart, as most apochromats are built to use three-lens systems for achieving images that are free of color fringes.

The 152ED can be purchased as a separate optical tube assembly, but it is most often coupled with Meade's CDS (Computer Drive System), a full, go-to computer-controlled drive system on a heavy German equatorial mount.

nebulae are brighter than you might expect. Interested? The best feature of the SkyView Pro 120 may be the very low price tag (under \$600 for the entire setup, even with the dual-axis drive system).

The telescope comes with a motor-driven equatorial mount and a sturdy, adjustable-height tripod with tubular steel legs. Included with the telescope are a 6x30 finder scope and two 1¼" eyepieces with an adapter to fit the 2" focuser.

Tele Vue Ranger

The Tele Vue Ranger is a high-quality 2.7-inch $f/6.8$ refractor. If you travel a lot and want the highest optical quality in the lightest package, the Ranger may be the scope for you. It weighs only 3.3 pounds

camera tripod or Tele Vue's own Tele-pod mount. The tube may be ordered in either an evergreen finish or brass. Two soft carrying cases are optional.

Tele Vue NP 127

If Tele Vue's Ranger isn't quite large enough for you, try their new NP 127. This 5-inch $f/5.2$ refractor collects more than three times as much light as the Ranger, making a substantial gain.

The NP 127 is classified as an apochromat, but the objective combines four separate lenses, a design known as a Petzval objective. In fact, the NP in the name stands for "Nagler-Petzval" to indicate that the designer (Al Nagler) has slightly modified the original design. The focal ratio,

If you travel a lot and want the highest optical quality in the lightest package, the Ranger may be the scope for you.

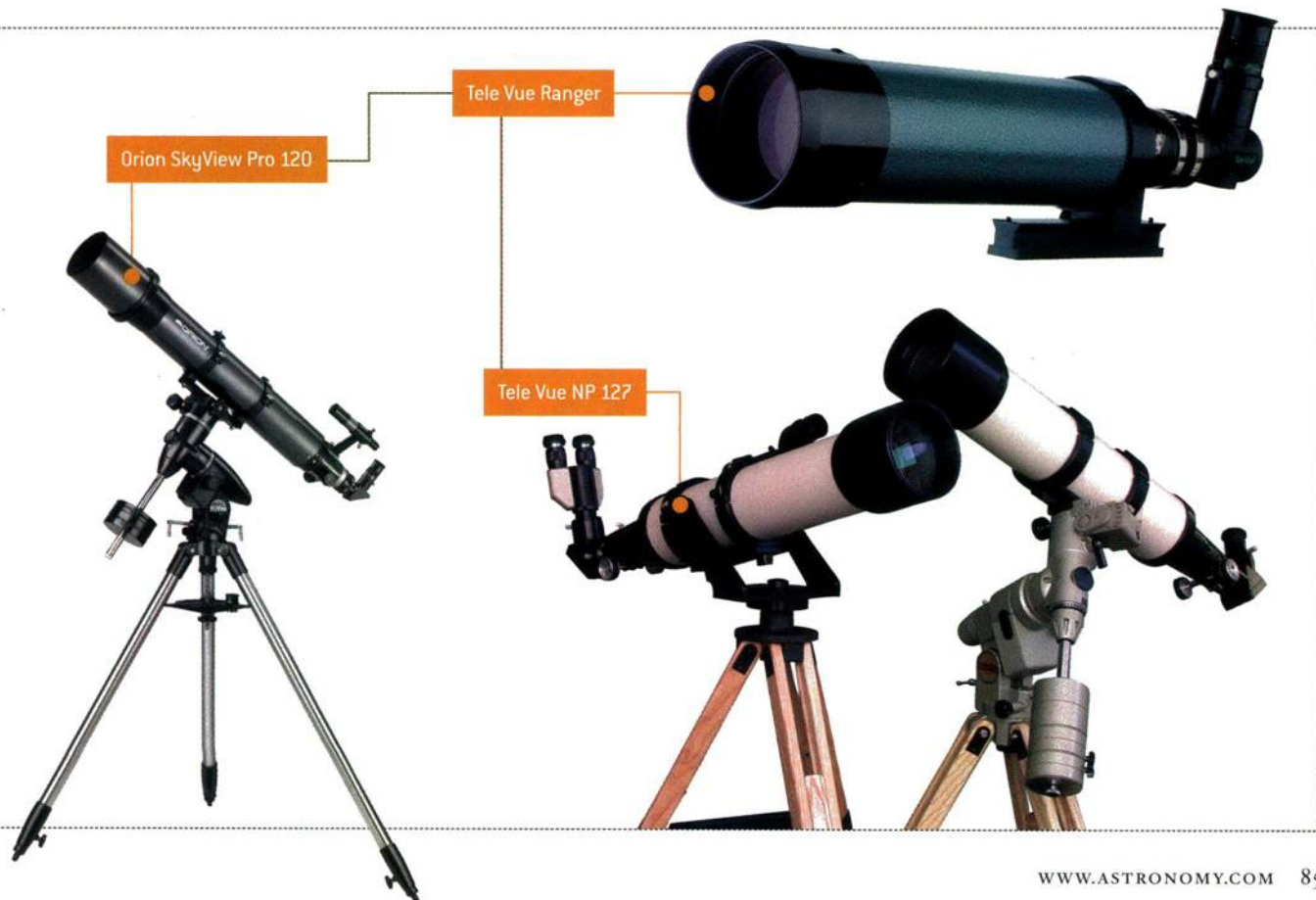
Orion SkyView Pro 120

The SkyView Pro 120 is a 4.7-inch $f/8.3$ achromat. Its unobstructed aperture collects 38 percent more light than a 4-inch scope, so images of planets, clusters, and

and is less than 18 inches long with the star diagonal attached.

The Ranger is sold without a mounting, but one of its options is a mounting bar that allows it to be attached to a small

5.2, falls in the "fast" class, indicating this scope was built for astrophotography. But if you plan a lot of high-power visual observing, add a Barlow lens or a Powermate from the Tele Vue line.



Aesthetically and mechanically, the NP 127 shines. The ivory-colored tube (you must purchase a mount and tripod for it separately) weighs only 14 pounds. The telescope accepts 2" eyepieces and comes with a sliding dew shield, tube rings, 2" diagonal, 1¼" adapter, and a fitted, hard-shell carrying case.

REFLECTORS

Celestron C8-N

Refractors are great, but you simply cannot beat the cost-per-inch ratio of a Newtonian reflector. Celestron's C8-N is a good example. Its 8-inch aperture will pull in thousands of deep-sky objects, and the scope is easy to set up and use. The C8-N is a "fast" system (f/5), but its 1000mm

weather permitting. It sits on Celestron's CG-5 German equatorial mount and tripod. The motor drive for this mount is a good option to add. The focuser accepts 2" eyepieces and a 1¼" adapter is included. A 9x50 finder scope and a 20mm Plössl eyepiece (50x) also come with the scope.

Mag 1 Instruments PortaBall 8

The 8-inch f/6 PortaBall 8 is an easily transported, lightweight telescope with a very different design and great optics. Its roots lie in the Dobsonian revolution, but the base of the PortaBall 8 is a 15.5-inch-diameter seamless fiberglass sphere that turns in any direction when the scope is moved.

In taking the telescope apart for travel, the upper tube assembly fits inside the

mirror), Mag 1's own Helical-Crayford focuser, and Rigel Systems' excellent zero-power Quik Finder, which displays a reticule on the sky.

Meade 12.5-inch Starfinder Dobsonian

If large aperture on a budget is what you're after, Meade's 12.5-inch f/4.8 Starfinder Dob is for you. Meade also offers an equatorial mount for the optical tube assembly, but I very much like it with the Dobsonian mount. (Meade offers the same pair of mountings for their 16-inch Starfinder as well, if you want an even bigger scope.)

The look and feel of this 12.5-inch telescope is pleasing, with its shiny white tube and white Dobsonian base. The motions are

The 8-inch f/6 PortaBall 8 is an easily transported, lightweight telescope with a very different design and great optics.

focal length provides good magnification when used with eyepieces shorter than 10mm or with a quality Barlow lens.

The C8-N arrives complete with everything you'll need to observe that night,

ball, while the truss tubes are carried in their own container. The entire PortaBall 8 weighs only 31 pounds. Other standard features include a curved, single-vane spider (the support for the scope's secondary

smooth and the balance is good. This means the scope stays put wherever you point it.

The 12.5-inch Starfinder is complete right out of the box. It comes with a 2" focuser and a 1¼" adapter, an 8x50 finder



scope, and a 26mm Super Plössl eyepiece that yields 59x.

Orion SkyQuest XT8

Ordinarily, I'd shun a telescope that advertises a feature called the "Correct-Tension Friction Optimization system" — it sounds way, way too techie. But the XT8 Dobsonian reflector from Orion Telescopes is too good to pass up.

10mm (120x) Plössl eyepieces, as well as a basic, no-frills, 6x30 finder scope. Buyers who intend to go hunting for galaxies and other faint targets will want to upgrade the finder to an 8x50 or 10x50 right away.

Orion StarBlast

Orion Telescopes markets this telescope for "kids." I must be a kid, then. This is an inexpensive, 4.5-inch f/4 wide-field scope

a classic Newtonian reflector from the 1950s. The real joy, however, comes in using it. To tell the truth, many of yesteryear's Newtonians were not built very well, and when I observed with one of them, I could feel the lack of quality. The Superior 10-inch f/5, however, is a telescope anyone would be proud to own. Its fine qualities start with the rack-and-pinion focuser, proceed to the white fiberglass tube, and

The CTFO system is a set of springs that puts tension on the altitude bearings, ensuring smooth motion and good tube balance.

The CTFO system, as it turns out, is a set of springs that puts tension on the altitude bearings. This ensures smooth motion and good tube balance. The springs also keep the tube attached to the base, so the entire telescope and mounting (tube, 19 pounds; base, 23 pounds) can be picked up using the supplied handle.

The optics center around an 8-inch f/5.9 primary mirror. The tube is made of enameled steel and has a rack-and-pinion focuser that accepts either 2" or 1¼" eyepieces. The telescope comes with 25mm (48x) and

that can be collimated — unlike, for example, Edmund Scientific's Astroscan. (Collimating a telescope means aligning all the optical elements for top performance. It's a simple yet necessary chore with any reflector.) The StarBlast is portable, weighing 13 pounds and measuring just 18 inches long. A built-in handle allows you to cart it off with one hand.

Parks Optical Superior 10-inch

The Superior 10-inch by Parks Optical has all the pleasing lines and solid detailing of

culminate with engraved setting circles and matched gears. These let you move the tube smoothly and easily.

The focuser accepts 2" eyepieces (two 1¼" eyepieces are provided). Also supplied are features that often count as extras with other manufacturers. You get an equatorial mount with a low-voltage clock drive, a dual-axis drive corrector, a 120VAC power supply, a 6-inch-diameter steel pier with three cast legs (each with a leveler), and a rotating ring system that makes it easy to position the tube for observing.



Starmaster 14.5-inch

The 14.5-inch Starmaster truss-tube Dobsonian is an ideal “large” scope for many people. It’s not too heavy (the mirror in its cell weighs 33 pounds), and the telescope is only 65 inches high when pointed straight up. This is an important feature for anyone who doesn’t want to climb up and down a ladder all night.

The secondary mirror assembly attaches to the rocker box (which holds the primary mirror) using four trusses made of eight lightweight tubes. It’s worth noting that you erect the scope by hand — no tools needed. With a short focal ratio, 4.3, an optical device known as a ParaCorr (parabolic corrector) is a valuable option. The ParaCorr,

month wait due to the demand. But this telescope is well worth it.

Starmaster 20-inch

The first object my wife observed through a 20-inch Starmaster was the Ghost of Jupiter (NGC 3242), and it took her breath away. Someday, I’ll say to her, “Sweetie, it’s time to buy a 20-inch Starmaster.” Her response, I expect, will be, “Great!” This impressive telescope gathers 90 percent more light than the Starmaster 14.5-inch model. Like its smaller cousin, the 20-inch also is f/4.3, but unlike the 14.5-inch, the eyepiece height of the Starmaster 20-inch when the scope is pointed straight up is 86 inches; you’ll need a ladder.

COMPOUND TELESCOPES

Celestron CGE-1100

Are you ready for a complete, large-aperture telescope system? The CGE-1100, Celestron’s 11-inch f/10 system, is a full go-to equatorial telescope and mounting that will please you every time you use it.

Because the scope is on an equatorial mount, it needs no other parts for long-exposure astrophotography. On alt-azimuth systems with motor drives, the field rotates during the exposure and becomes noticeable in any exposure running longer than a few seconds. Correcting this requires either a proper equatorial mount or an expensive add-on device called a field de-rotator.

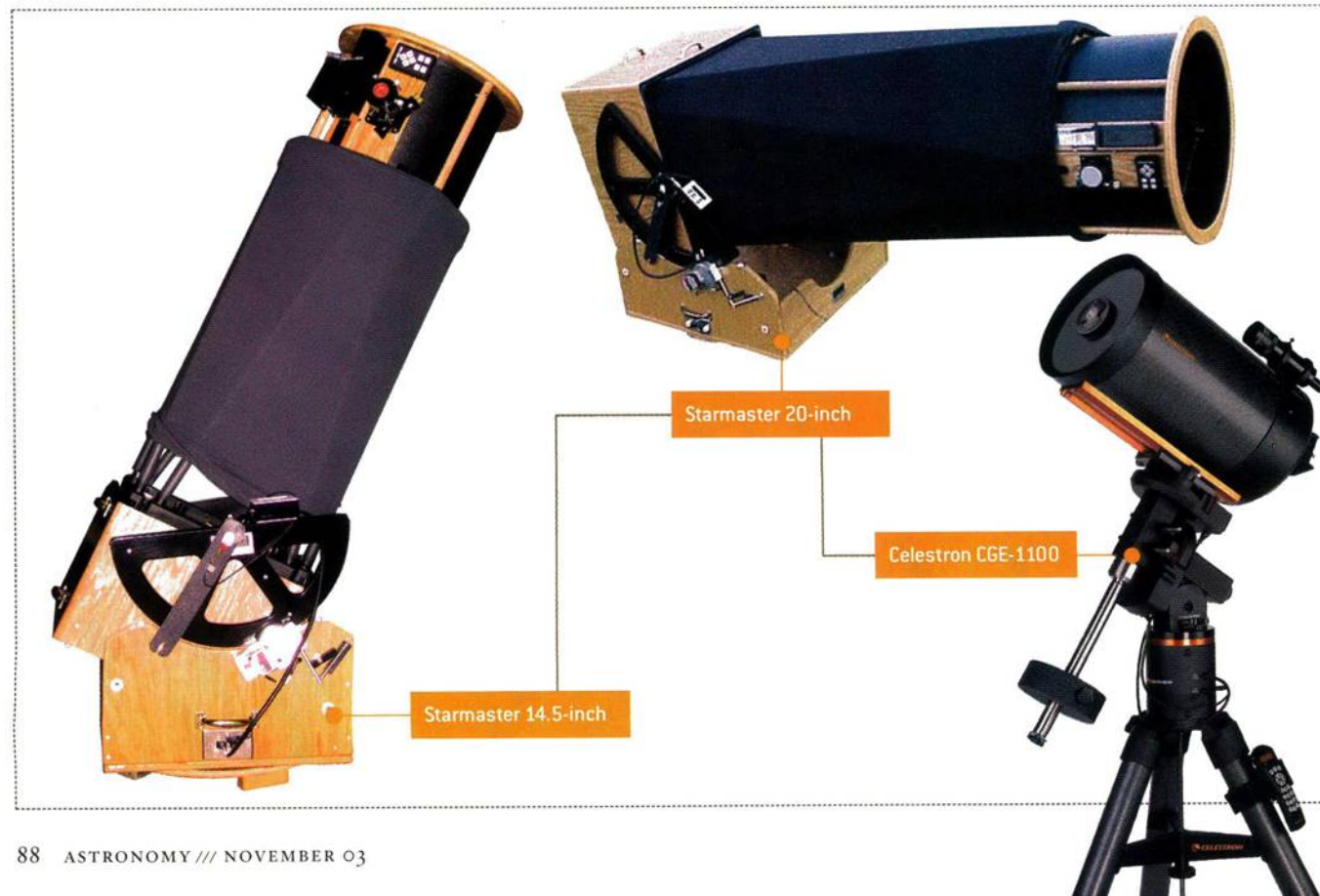
The CGE-1100, Celestron’s 11-inch f/10 system, is a full go-to equatorial system that will please you every time you use it.

made by Tele Vue Optics, increases the usable field of view. It fits into the focuser ahead of the eyepiece, adding 15 percent to the magnification.

Starmaster’s owner personally tests each assembled scope before it’s delivered. The only problem with this telescope is the six-

Before ordering a Starmaster 20-inch, note that the rocker box, mirror box, and the mirror in its cell weigh 40, 38, and 59 pounds, respectively. One person can assemble this scope, although not as easily as the 14.5-inch. Expect to wait approximately six months for this scope, too.

The CGE-1100 has a carbon-fiber tube weighing 27.5 pounds, which is light for its size. The mount and tripod, however, scale out a bit heavier: 114 pounds combined. This scope will accept 2" eyepieces but comes with a 1¼" visual focuser, star diagonal, and 40mm (70x) Plössl eyepiece.



Celestron NexStar 8i

Let's be honest. At first glance, the NexStar 8i looks, well, funky. Its fork arm is really only half a fork, and the hand paddle

ITE Telescopes Intes MK67

The Intes MK67 is a portable 6-inch Maksutov-Cassegrain telescope. With a focal length of 1,800mm and focal ratio of

Meade ETX-90EC

Compact, lightweight, easy to set up and use — these are attributes of a great travel scope, and that's what the Meade ETX-

The Meade 12-inch f/10 LX200 GPS is the dream scope of many observers I know.

looks like a telephone stuck to the side of the telescope. So what? This scope performs superbly, and the missing half-fork decreases the weight, making it easier to transport. The NexStar 8i is an 8-inch f/10 system. With the addition of an optional computerized hand controller, it has full go-to capability. (A standard hand controller comes with the scope.)

The tripod for the NexStar 8i must be purchased separately. In theory, you could place the scope on a table, but I've yet to see a table sturdy enough. In the field, the scope runs on eight AA batteries. But if you plan to observe anywhere near a source of electrical power, I strongly recommend you buy the optional AC adapter and do not use the batteries. In the long run, the adapter will save you a lot of money. The NexStar 8i comes with a 1¼" visual back and a 25mm (81x) Plössl eyepiece.

12.5, the MK67 is a serious planetary observer's scope.

One of the highlights of this telescope is its low weight — only 9.5 pounds. The optical tube assembly has a carry handle, and it also comes with a padded travel bag. A 2" Crayford focuser is standard, as is a 7x35mm straight-through finder scope. (A 10x50 finder scope, straight-through or right angle, is a worthwhile option.) You must buy a mount and tripod for this telescope separately.

The Deluxe model of the MK67 replaces the standard Pyrex mirrors with ones made of Sital, a low-distortion ceramic less affected by temperature changes. The Deluxe version also guarantees slightly higher optical quality overall ($\frac{1}{4}$ to $\frac{1}{2}$ wave versus $\frac{1}{2}$ to $\frac{3}{4}$ wave), and it supplies 96-percent-reflectivity dielectric coatings on the mirrors.

90EC is. Add the optional Autostar Computer Controller (which I highly recommend) and the telescope becomes a full go-to system.

Optically, the ETX-90EC is a 3.5-inch Maksutov-Cassegrain system with a focal ratio of 12. It operates on eight AA batteries, but — as with any telescope that lists the option — it's best to buy the AC adapter. Meade's Deluxe Field Tripod is a necessity for this telescope. Meade and its dealers sometimes offer the tripod (and even the Autostar Hand Controller) as a package deal with the ETX-90EC, turning a good buy into a great deal.

Meade 12-inch LX200 GPS

I like large telescopes. I also like easy-to-use telescopes. And I love large, easy-to-use telescopes. The Meade 12-inch f/10 LX200 GPS is the dream scope of many



observers I know. GPS in the name means that when the drive is powered up, it electronically acquires signals from as many of the orbiting Global Positioning System satellites as are above the horizon. It figures out where the scope is, as well as the date and time. Next, it uses an internal compass first to find magnetic north, then true north. (This sounds, and actually is, pretty complex, but so far all we've done is turn on the power and press just one button on the hand controller.)

Then, the computer checks and compensates for the mount not being level. Finally, the computer locates a bright star (which it knows is above the horizon). You look through the eyepiece and center the star. Do this for a second star to align the drive and go-to system, and it's time to observe.

The telescope comes complete. The scope's 3,048mm focal length gives impressive views with eyepieces that would be considered low power on other scopes. An excellent standard piece of equipment is Meade's Zero Image-Shift Microfocuser, which prevents annoying image shifts when you turn the telescope's focus knob.

Questar 3.5-inch Standard

The Questar Standard 3.5 has been in continuous production longer than any other

telescope in the world. Long before the Dobsonian revolution, SCTs, or ultra-wide-angle eyepieces, there was the Questar 3.5. The reasons for its longevity are quality mechanical construction, portability, and optical excellence.

The Questar Standard 3.5 stores in a carrying case that also houses its tabletop legs, solar filter, and AC adapter cord (all included in the price). It's a very compact package that travels well. The Questar 3.5 is beautiful, too. The equatorial fork mount is brushed aluminum, the tube is silk-screened with a map of the Moon, and the adjustable, sliding dew cap is a star chart.

Optically, the Questar 3.5 is an f/14.4 Maksutov-Cassegrain. Its focal length is 1,300mm, pretty good for such a small package. The mount provides manual alt-azimuth controls and an AC-powered drive motor is built into the base.

Takahashi CN-212

If you're like me, two telescopes for the price of one sounds like a sweet deal. It is — if the scope is the Takahashi CN-212. CN stands for Cassegrain-Newtonian and this telescope, which employs a replaceable secondary mirror, contains both optical systems.

The standard setup of the CN-212 is as an 8-inch f/12.4 Cassegrain telescope.

Remove the hyperbolic secondary and replace it with the flat secondary, however, and the scope becomes a wide-field, 8-inch f/3.9 Newtonian. Both optical configurations show pinpoint stars — the best of both worlds.

The CN-212 is available as an optical tube assembly only. It is most often paired with Takahashi's motor-driven EM-200 Temma II mount.

Takahashi Mewlon 250

Takahashi's Mewlon 250 is a 10-inch f/12 Dall-Kirkham system. The Dall-Kirkham design is a Cassegrain with an elliptical primary mirror and a spherical secondary mirror. The focal length is an impressive 3,000mm, which provides nice magnification of smaller celestial objects such as planets and planetary nebulae.

The optical tube assembly of the Mewlon 250 weighs 27 pounds, so it needs an equally beefy mount. As with the CN-212, the Mewlon 250 makes a good match for Takahashi's motor-driven EM-200 Temma II mount.

A nice feature of this scope is the permanently affixed 7x50 finder. Yes, it's good optically, but it also functions as a carrying handle for the optical tube if you support the tube with your other hand.



Astro-Physics

11250 Forest Hills Road
Rockford, IL 61115
[t] 815.282.1513
[w] www.astro-physics.com

Celestron International

2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

Coronado

Anacortes Telescope & Wild Bird
9973 Padilla Heights Road
Anacortes, WA 98221
[t] 360.588.9000
[w] www.buytelescopes.com

ITE Telescopes

Bray Imaging Technologies

Cherrycourt Way
Leighton Buzzard
Bedfordshire LU7 4UH, United Kingdom
[t] 011.44.1525.219100
[w] www.brayimaging.co.uk

Mag 1 Instruments

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New Berlin, WI 53151
[t] 262.785.0926
[w] www.mag1instruments.com

Meade Instruments Corporation

6001 Oak Canyon
Irvine, CA 92618
[t] 800.626.3233
[w] www.meade.com

Orion Telescopes

P.O. Box 1815
Santa Cruz, CA 95061

[t] 800.676.1343
[w] www.telescope.com

Parks Optical

P.O. Box 716
Simi Valley, CA 93062
[t] 805.522.6722
[w] www.parksoptical.com

Questar Corporation

6204 Ingham Road
New Hope, PA 18938
[t] 215.862.5277
[w] www.questarcorporation.com

Starmaster Portable Telescopes

2160 Birch Road
Arcadia, KS 66711
[t] 620.638.4743
[w] www.starmastertelescopes.com

Takahashi

Land, Sea, and Sky
3110 S. Shepherd Drive
Houston, TX 77098
[t] 713.529.3551
[w] www.takahashiamerica.com

Telescope Engineering Company

15730 W. 6th Avenue
Golden, CO 80401
[t] 303.273.9322
[w] www.telescopengineering.com

Tele Vue Optics

32 Elkay Drive
Chester, NY 10918
[t] 845.469.4551
[w] www.televue.com

TEC 6

TEC is short for Telescope Engineering Company, builders of custom telescopes. On average, it takes about four months to receive a TEC telescope once you place an order, but it's worth the wait.

The TEC 6 is a 6-inch f/12 Maksutov-Cassegrain optical tube assembly. You'll

have to supply your own mount and tripod. The mount need not be a huge one, however, as the TEC 6 weighs only 10 pounds and is just 20 inches long. The focuser accepts 2" eyepieces or diagonals.

The primary mirror of the TEC 6 is Pyrex, but a mirror using low-distortion quartz as the substrate (the material that is

coated with aluminum) is an option. The front corrector plate has an anti-reflection coating, and the mirrors have enhanced coatings to increase reflectivity.

TEC MC200

Last, and certainly not least, there's the TEC MC200, an 8-inch f/15.5 Maksutov-Cassegrain. The focal length is 3,150mm — perfect for planets — yet it fits into an optical tube only 26 inches long. (Mounting and tripod are not included.)

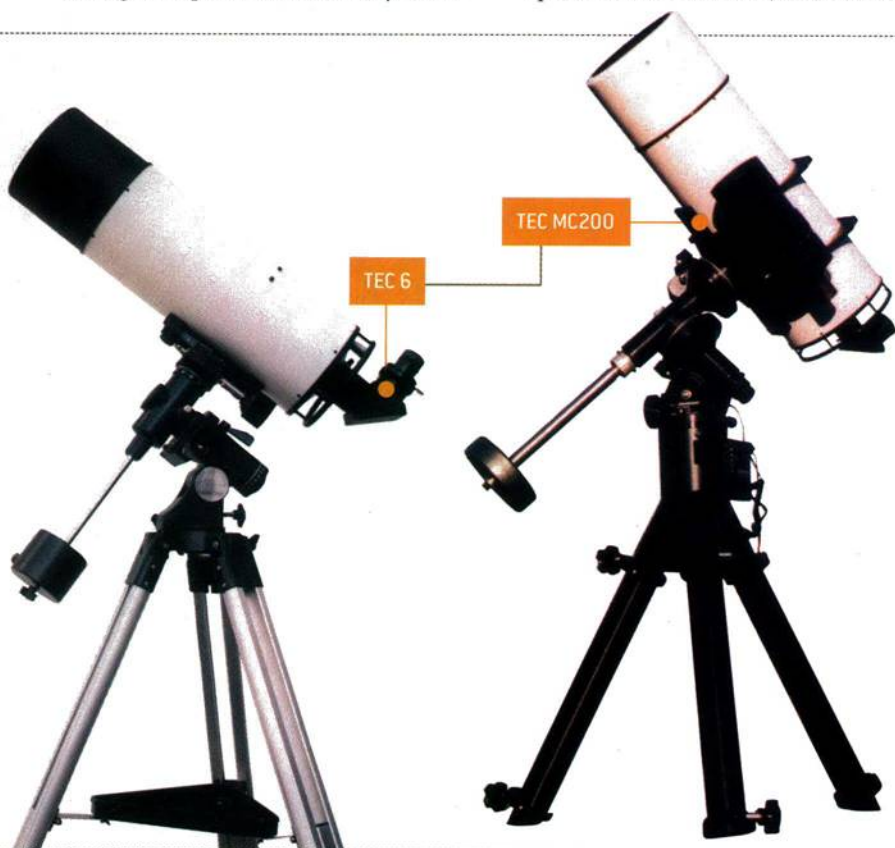
The rest of the specifications for the MC200 read like a list of what to do right when building a telescope: The primary mirror is made of quartz, a material that offers low expansion and rapid cooling; all optics are coated on all surfaces; and the tube has an internal venting fan operated by a small hand controller.

This telescope is TEC's best seller in the 8-inch size, and it's easy to see why. The optics are excellent, the focusing is smooth, and the fit and finish are top-notch. The focuser accepts 2" eyepieces, and the TEC 6 is made for high power.

Whatever your observing style — and no matter what objects you like to view — I'll bet somewhere among these 25 telescopes you'll find one that can deliver on all your celestial dreams. ■



To learn more about these telescopes, visit www.astronomy.com/toc





{ NEW PRODUCTS }



1. Celestron CGE-1400 SCT

Collecting more than three times the light of an 8-inch telescope, this 14-inch Schmidt-Cassegrain is the largest in the CGE series. Its sturdy German equatorial mount features the NexStar go-to control system and provides a solid platform for long-exposure photography. With a resolution of 0.39", the scope comes with a 2" eyepiece, a 2" star diagonal, a 1 1/4" adapter, and a 9x50 finder.

\$5,799; Celestron
2835 Columbia Street
Torrance, CA 90503
[t] 310.328.9560
[w] www.celestron.com

2. Color Electronic Imaging Eyepiece

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\$119; Orion Telescopes & Binoculars
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3. ImageView Digital Binoculars

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4. Art from the Soul holiday cards

'Tis the season to be jolly and — if you're the organized type — to send holiday cards letting family and friends know they're in your thoughts. Astronomical artist Julie Rodriguez Jones offers seasonal cards that feature such celestial phenomena as aurorae and meteors. The half-sheet (pictured) price is listed below; quarter-sheet cards run \$1.25 each for 10 or more.

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The origin of things

Alpha & Omega: The Search for the Beginning and End of the Universe

Charles Seife, 304 pages, Viking, New York, 2003; ISBN 0-6700-3179-8; hardcover, \$24.95.

Two big questions define the realm of cosmology: Where did we come from, and where are we going? Just a century ago, both questions were beyond the reach of science, but recent years have seen dramatic progress on both fronts. Charles Seife, a bright, energetic, and articulate cosmology-beat reporter, has given us an engaging account of these strides.

Alpha & Omega is a ripped-from-the-headlines guide to cosmology that puts all manner of bizarre phenomena — dark matter, the accelerating universe, cosmic microwaves, supersymmetry, superstrings, quark-gluon plasma, supernovae, the multiverse, and oscillating neutrinos — into a coherent picture of the cosmos.

The beginning now can be traced to the quark soup that existed during the first 10 microseconds after the Big Bang. Mounting evidence suggests the largest things in the current universe — galaxies, clusters of galaxies, and superclusters — began as subatomic quantum fuzz that blew up almost to today's sizes during a tremendous burst of expansion known as inflation.

The end is coming into focus, too. The expansion of the universe is speeding up, not slowing down. If this trend continues, in 100 billion years only a few hundred neighboring galaxies will be visible in the sky (compared to the few hundred billion galaxies seen today). But that's a big *if*: We know almost nothing about the dark energy that is driving the cosmic speedup.

Remarkably, most of this has been learned within the past five years. Cosmologists have been busy, and Seife has been there to report it. *Alpha &*

Omega makes almost all of it comprehensible, but the book includes some mistakes. Seife has Big Bang originator George Gamow calculating the universe's light-element abundances (he never did); the Big Bang–Steady State controversy beginning in the 1930s and lasting for decades (thankfully, the controversy lasted only from 1950 to 1965); and cosmic microwaves hard to detect because of earthly interference (even your TV can detect cosmic microwaves).

Most painful to me, Seife characterizes the 1980s as a period of obsession with the Hubble constant. I view them as the go-go days when the connections between elementary particles and the cosmos first were recognized and the revolutionary ideas of inflation, cold dark matter, baryogenesis, and quark soup all came to be.

Nonetheless, the reader will come away with a good understanding of the exciting advances of the past five years and will be prepared for those certain to come.

— **MICHAEL S. TURNER** is assistant director for math and physical sciences at the National Science Foundation.

The Big Splat, or How Our Moon Came to Be

Dana Mackenzie, 232 pages, John Wiley & Sons, Hoboken, New Jersey, 2003; ISBN 0-4711-5057-6; hardcover, \$24.95.

Considering the Moon is visible almost every day, it's a little surprising no one knew where it came from until about twenty years ago. That was when planetary scientists William Hartmann, Don Davis, Alastair Cameron, and William Ward proposed what's called the Big Splat, the Big Whack, or the Giant Impact scenario.

Dana Mackenzie's new book tells the story of how scientists figured out the

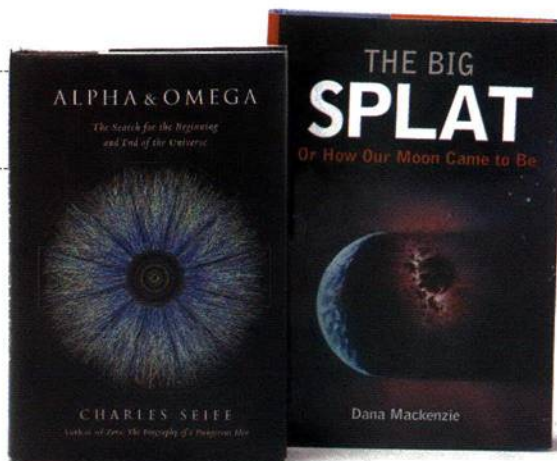
Moon was born from a gigantic, glancing collision between the proto-Earth and a Mars-sized object. The impact occurred about 50 million years after Earth began to form 4.57 billion years ago. The object barreled deep into the proto-Earth, shooting a cloud of incandescent debris into orbit. Within about a year, that debris had coalesced to make the Moon.

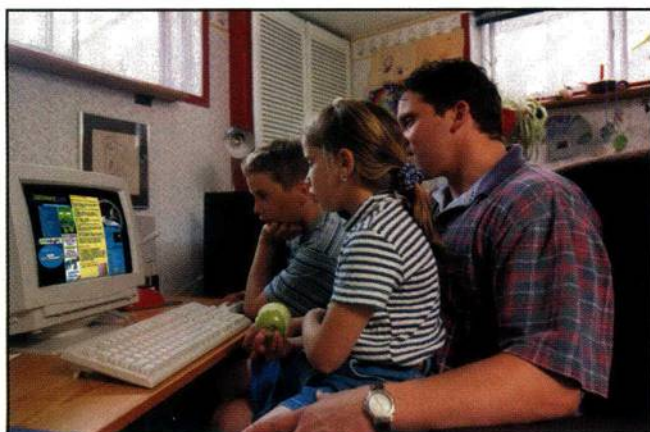
Mackenzie starts by briefly detailing ancient views of the Moon through the Scientific Revolution of the 17th century. The book really gets going in the fifth chapter, which profiles scientists who developed the main lunar-origin theories. These include George Darwin (son of the naturalist) and a colorful astronomer named Thomas Jefferson Jackson See.

Until recently, the three major theories were: The Moon was ripped from a rapidly spinning Earth; the Moon was born elsewhere in the solar system and was captured by Earth; the Moon formed at the same time and from the same cloud of debris as Earth.

The Space Age saw the end of all three ideas. Lunar samples showed that, while related to Earth, the Moon underwent a different formation. The details of that difference took a long time to emerge, a story Mackenzie explores well. The book's greatest strength, however, is how Mackenzie shows the emergence and acceptance of the Giant Impact scenario as scientists refined ideas in light of new data. It's an excellent and absorbing tale.

One criticism is the book's skimpiness on pictorial matter. But all in all, *The Big Splat* is a superb exploration of an important chapter in the history of Earth and its satellite. Every Moon-buff will want a copy. — **ROBERT BURNHAM** is a contributing editor of *Astronomy*. ■





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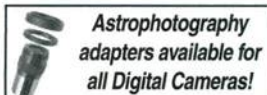
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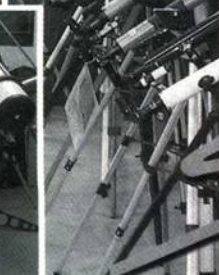


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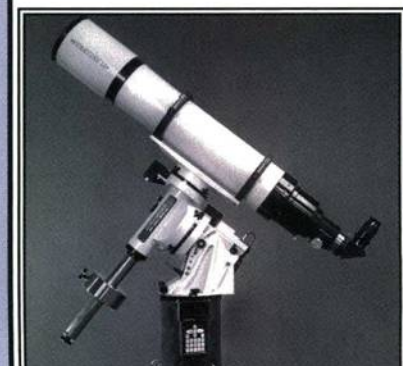
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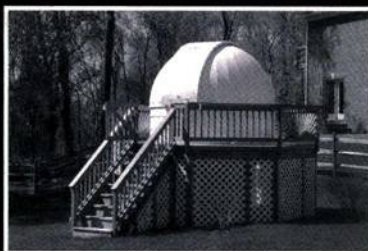
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During the next few months, the LodeStar Astronomy Center will more closely resemble an art museum than a science facility. Part of the New Mexico Museum of Natural History and Science in Albuquerque, the LodeStar currently hosts *Astro-Images*



THE LUNAR ECLIPSE on November 8 will beckon amateur astronomers and the general public alike to gaze at its ruddy glow for a quick 24 minutes of totality. TERENCE DICKINSON

of New Mexico, a contest and exhibit featuring images from astrophotographers. The theme for this event is "Portraits from the Foothills of Space."

Co-sponsored by the LodeStar and the Albuquerque Astronomical Society, this year's contest included categories in land and sky, film and plate format, and digital format. Representatives of the Albuquerque science community judged the images, and winners were announced in late August.

For more information, contact Karen Keese at 505.841.5972; e-mail, pr@taas.org; web sites, www.lodestar.unm.edu and www.taas.org.

ONGOING EXHIBIT

Impacts: Asteroids, Comets, and Meteorites

Dreyfus Planetarium, Newark Museum, Newark, New Jersey. Focusing on comet, meteorite, and asteroid impacts, this exhibit includes a photo panel of a comet

striking Earth, an impact time line, a diorama of the mile-wide Barringer crater in Arizona, and models of spacecraft used to explore these bodies. For more information, visit www.newarkmuseum.org.

10.24.03–10.25.03

All Arizona Star Party

Farnsworth Ranch, near Arizona City, Arizona. Sponsored by the East Valley Astronomy Club, this annual event features two nights of observing at a prime dark-sky venue between Phoenix and Tucson. For more information, e-mail Randy Peterson at rgpeterson@cox.net; web site, www.eastvalleyastronomy.org/EVAC/aasp.htm.

10.24.03–10.26.03

Blackwater Falls Astronomy Weekend

Blackwater Falls State Park, Davis, West Virginia. For more information, call 800.225.5982; web site, www.kvas.org.

11.07.03

Far Out Friday

Adler Planetarium, Chicago. On the first Friday of every month, the Adler hosts an evening of astronomy-related fun, including observing, lectures, interactive displays, special demonstrations, and Doane Observatory tours. For more information, call 312.922.7827; web site, www.adlerplanetarium.org.

11.08.03

Shreveport-Bossier Astronomical Society Star Party

Ralph A. Worley Observatory, near Shreveport, Louisiana. The lunar eclipse on this night will be the primary target for star party attendees. For more information, contact Cran Lucas at clucas@softdisk.com; web site, www.lsus.edu/nonprofit/sbas/party.htm.

11.09.03

Astrofestival

Oslo University Campus, Oslo, Norway. With a space suit competition, chance to manufacture a spaceship with LEGOs, and a scale solar system, this gathering should be of particular interest to children. For more information, visit www.astrofestival.no.

11.12.03

The Mystery of Black Holes

Smithwick Theater, Foothill College, Los Altos Hills, California. Alan Dressler of the Carnegie Institution will give a non-technical talk concerning black holes. For more information, call 650.949.7888.

11.15.03

North Texas Skywatch Star Party

Lake Mineral Wells State Park, near Fort Worth, Texas. With a family-oriented atmosphere, the North Texas Skywatch Star Party welcomes anyone interested in astronomy, regardless of experience. For more information, visit www.tarleton.edu/~planetarium.

11.16.03–11.23.03

Chiefland Star Party

Chiefland Astronomy Village, Chiefland,

Florida. This laid-back star party provides non-members a chance to view and participate in the great activities members of the Chiefland community enjoy year-round. For more information, visit www.c-av.com.

11.17.03–11.28.03

Canary Islands Winter School of Astrophysics

Puerto de la Cruz, Canary Islands, Spain. The theme for this meeting is "Payload and Mission Definition in Space Sciences." For more information, visit www.iac.es/gabinete/inves/congl.html.

11.17.03

Magnificent Mars

Oregon Museum of Science and Industry, Portland, Oregon. Sponsored by the Rose City Astronomers, author and astronomer Ken Croswell will discuss the exploration of Mars. For more information, call 503.255.2016; web site, www.rca-omsi.org.

12.05.03

Understanding the Most Distant Galaxies

Priory Street Centre, York, England. The York Astronomical Society welcomes University of Sheffield professor of astrophysics Clive Tadhunter, who will lecture on remote galaxies. For more information, visit www.yorkastro.freeseve.co.uk/meets.html.

01.04.04–01.08.04

American Astronomical Society Meeting

Hyatt Regency, Atlanta. This 203rd meeting of the AAS will feature lectures, discussions, and special events. For more information, visit www.aas.org. ■

CONTACT INFORMATION

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our on-line calendar at www.astronomy.com.

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RESOURCES

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ORDER OUT OF CHAOS

BOOKS — The definitive study on the subject has to be *The Galaxies of the Local Group* by Sidney van den Bergh (Cambridge University Press, New York, 2000). It provides amazing detail on all the member galaxies and discusses the stability and evolution of the Local Group as a whole. Van den Bergh also explains how knowledge of the Local Group informs astronomers about the formation and evolution of galaxies elsewhere in the universe.

WEB — Perhaps the best Internet source on the Local Group is the Students for the Exploration and Development of Space (SEDS) site at www.seds.org/messier/more/local.html. It contains detailed information on all suspected members of the Local Group (and nearby non-members), links to studies, and images.

The NASA/IPAC Extragalactic Database (affectionately known as NED) has a site exclusively devoted to the Local Group at nedwww.ipac.caltech.edu/level5/Mateo/table1.html. This table lists all the galaxies of the Local Group along with relevant information. It also provides links for each galaxy to the main NED pages, which include exhaustive listings, images, and references for each object.

ABSURD UNIVERSE

BOOKS — For a look at dark matter from an acknowledged expert, read *Bright Galaxies, Dark Matters* by Vera C. Rubin (Springer-Verlag, New York, 1998).

Although somewhat dated already, this is a classic reference book on the topic.

WEB — A large number of professional papers have been collected on-line at panisse.lbl.gov/~evlinder/sci.html. Articles are in postscript (.ps) and Adobe Acrobat Reader (.pdf) format. The papers feature authors such as Martin White ("Dark Energy and the Cosmic Microwave Background"), Michael Turner ("Dark Energy and the New Cosmology"), and Steven Weinberg ("Importance of Discovering the Nature of Dark Energy").

GREAT BALLS OF FIRE

BOOKS — Scientific papers from a conference on globs can be found in *Globular Clusters*, edited by C. Martinez Roger et al. (Cambridge University Press, New York, 1999). Observers will find tips and techniques on how to view globular clusters in handbooks such as David Eicher's *Deep-Sky Observing with Small Telescopes: A Guide and Reference* (Enslow Publishers, Hillside, New Jersey, 1989) or Steven Coe's *Deep-Sky Observing: The Astronomical Tourist* (Springer-Verlag, New York, 2000).

ARTICLES — Some interesting stellar phenomena occur in the close quarters of a glob. Read about what the Chandra X-ray Observatory uncovered about low-mass x-ray binaries, millisecond pulsars, and white dwarfs that consume matter from nearby companions in "Dynamical Formation of Close Binary Systems in Globular Clusters" by David Pooley et al. (*Astrophysical Journal*, v. 591, p. L131).

WEB — The SEDS web site provides background information on globular clusters and links to globular clusters in the Messier Catalog at www.seds.org/messier/glob.html. A listing of the Milky Way's approximately 150 globular clusters (including coordinates for each cluster and its distance from the Sun and the galaxy's center, among other data) is posted on the web site of McMaster University's William Harris at physwww.physics.mcmaster.ca/%7Eharris/mwgc.dat.

EXPLORING THE PINWHEEL

BOOKS — For more information about observing M33, check out *Burnham's Celestial Handbook*, volume 3 (Dover Publications, New York, 1978). The author, Robert Burnham, devotes seven pages to the Pinwheel Galaxy.

WEB — If you own a large telescope, try an observing challenge on Rich Jakiel's Adventures in Deep Space web site. A project for observing globular clusters in M33 is located at www.angelfire.com/id/jsredshift/gcm33.htm.

DIAMONDS IN THE RINGS

BOOKS — Hobbyists will enjoy Dan Bortolotti's *Exploring Saturn* (Firefly Books, Toronto, 2003), which includes a history of studies on the planet as well as tables on when to view it. Keep your eyes peeled this spring for a new book by Jay Anderson and contributing editor Stephen Edberg. These two veteran sky-watchers provide useful tips and techniques in *Observing Eclipses, Transits, and Occultations* (Cambridge University Press, New York, 2004).

WEB — The Association of Lunar and Planetary Observers maintains a web site on observing the Ringed Planet at www.lpl.arizona.edu/~rhill/alpo/sat.html. There, you can find ephemerides for Saturn, papers and information about occultations by the planet, and links to collaborative projects between amateur and professional astronomers.

A NIGHT WITH THE FERAS

BOOKS — *Firefly Astrophotography Guide* by H. J. P. Arnold (Firefly Books, Toronto, 2003) is a good place to begin your adventure in astrophotography. This highly illustrated book details the processes involved in producing good astronomical images. *Practical Astrophotography* by Jeffrey R. Charles (Springer-Verlag, New York, 2000) is another great reference for amateurs wanting to do astrophotography.

WEB — If you want to learn more about Bob and Janice Fera, what better web site to visit than their own? Check them out at www.feraphotography.com, and don't miss the links page. It lists the web sites of many other excellent astrophotographers.

If you'd like to try your hand at astrophotography but don't have the equipment, there is an alternative: Kitt Peak National Observatory offers an *Advanced Observing Program*. Spend one or two nights on the mountain using a 20-inch telescope to image celestial delights of your choosing. The program's web site is located at www.noao.edu/outreach/aop. ■

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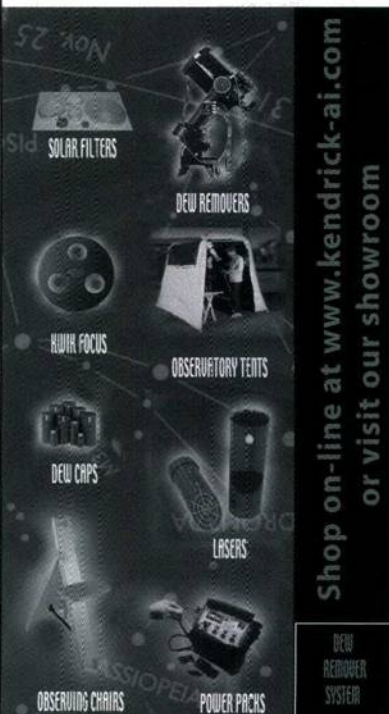
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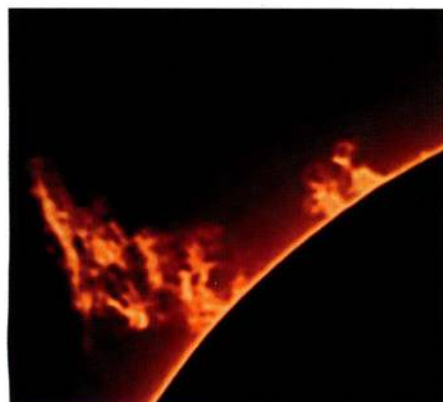
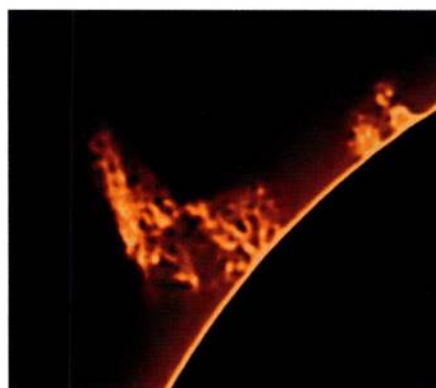
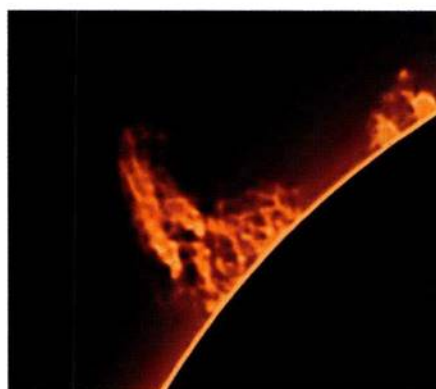
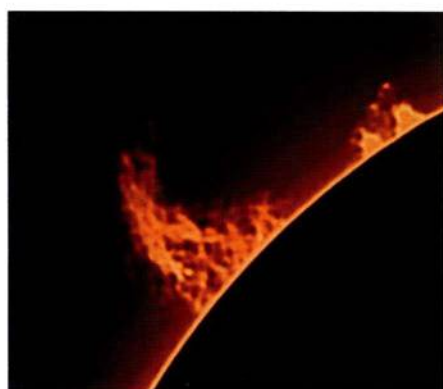


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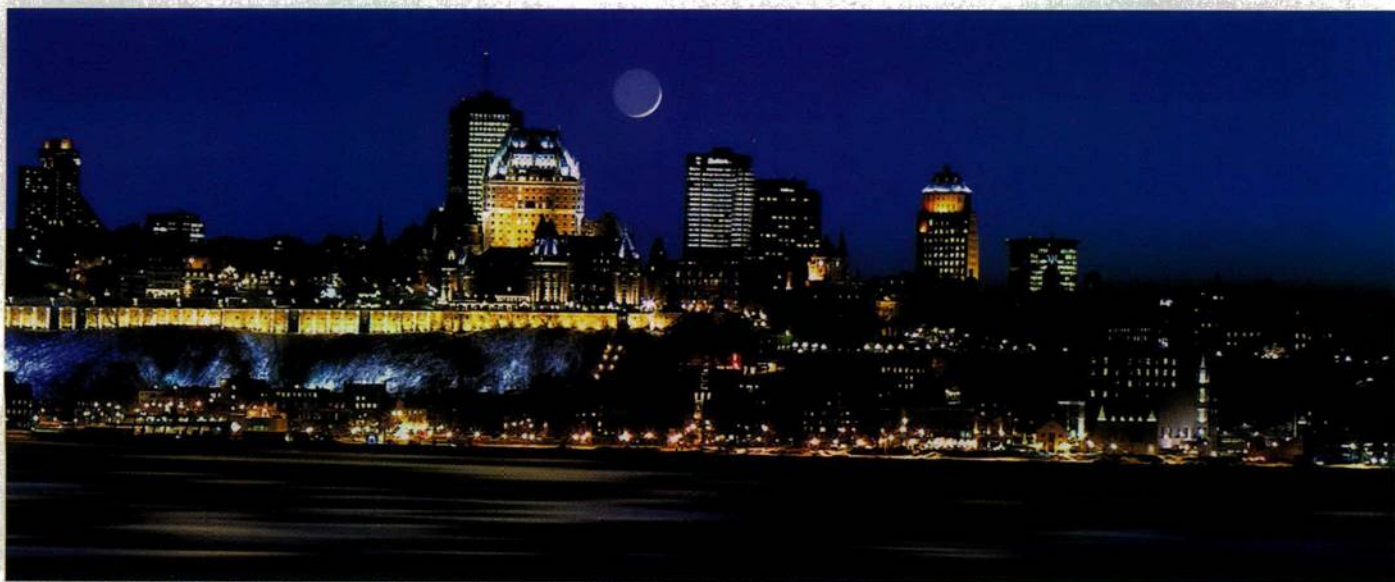
THE ACTIVE SUN

Eruptive prominence sequence

The Sun emits light at many different wavelengths, a tiny percentage of which reaches us as hydrogen-alpha radiation, also known as $H\alpha$. The specific wavelength of $H\alpha$ light is 656.28 nanometers, and it has a very red color. Amateur astronomers use $H\alpha$ filters to observe and photograph the Sun's chromosphere and prominences, both of which are bright at this wavelength. Observing the Sun in $H\alpha$ is fun because there's lots of activity and things change in real time. Prominences along the Sun's limb (or edge) form, grow, shrink, and disappear, often in the span of a few hours. Solar flares, which appear in $H\alpha$ light as bright white patches on the Sun's disk, may come and go in a matter of minutes.

Left. **$H\alpha$ PROMINENCE SEQUENCE** (Celestron FirstScope 80EQ refractor, Coronado ASP-60 hydrogen-alpha filter. Each image is a composite of 50 detailed frames selected from six 20-second AVI files taken on May 7, 2003, from Gambugliano, Italy.) /// **MARCO LORENZI**

Send your photos to: ASTRONOMY Reader Gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com. Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.



*Top, **THE LUNAR CRATER CLAVIUS*** [Celestron 11-inch Schmidt-Cassegrain telescope, Phillips ToUcam Pro webcam, 2x Barlow lens. The best 50 of 600 frames were selected and combined.] /// **JOHN S. SUSSENBACH**

*Above, **EARTHSHINE OVER THE ST. LAWRENCE RIVER*** [Canon D30 digital camera, 50mm lens at f/2; 5-second, tripod-mounted exposure; taken May 3, 2003, just outside Quebec City, Canada] /// **JAY OUELLET**



Top left, SUPERNOVA REMNANT IC 443 IN GEMINI [Takahashi FSQ 4-inch refractor at f/5.3, SBIG ST10XME CCD camera, LRGB exposures of 40, 40, 40, and 64 minutes, respectively] /// DANIEL B. PHILLIPS

Top center, THE DARK NEBULA VAN DEN BERGH 142 IN CEPHEUS [Optical Guidance Systems 12.5-inch Ritchey-Chrétien telescope at f/7.5, FLI IMG1024 CCD camera, 2-frame mosaic, each a 120-minute exposure] /// ROBERT GENDLER

Above, OPEN CLUSTER M46 AND PLANETARY NEBULA NGC 2438 IN PUPPIS [Celestron 11-inch Schmidt-Cassegrain telescope at f/6.5, 35mm camera at prime focus, Fuji S-800 film, 15-minute exposure] /// TOM DIANA



Top right, GLOBULAR CLUSTER M3 IN CANES VENATICI (RC Optical Systems 16-inch Ritchey-Chrétien scope at f/8, SBIG ST10XME CCD camera, LRGB exposures of 20, 5, 5, and 5 minutes, respectively.) /// **ELLIOT GELMAN, DUKE CREIGHTON, AND ADAM BLOCK**

Above, SPIRAL GALAXY NGC 253 IN SCULPTOR (Meade 16-inch LX200 Schmidt-Cassegrain telescope, 35mm camera at prime focus, two 60-minute exposures on Fuji HG400 film, negatives scanned and digitally combined.) /// **JASON WARE**

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SPECIFICATIONS: 8" LX90 —

Each complete telescope includes 8" f/10 Schmidt-Cassegrain optical tube assembly with MgF₂ coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally; see below); double-time fork mount with dual-axis 4.9" worm gears and control panel; electric slow-motion controls on both axes; Autostar hand controller with digital readout display, 9-speed drive controls on both axes, and GO TO controller; 30,223-object onboard celestial software library; internal battery port; accepts 8 (user-supplied) C-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); 8 x 50mm viewfinder; 1.25" diagonal prism; Series 4000 Super Plössl 26mm eyepiece; standard field tripod; Autostar Suite with imager; operating instructions. **\$1695.** **Ultra-High Transmission Coatings (UHTC) group** increases image brightness by about 20%; add **\$175.** Packing & shipping in the 48 states: \$95.



Buy a **\$650** Super Plössl eyepiece set for your LX90 telescope for only **\$99!** See ad in this issue for details!

Included with LX90:

Meade Autostar Suite including LPI imager

A **\$149** value!

See ad in this issue for details!



ADVANCED PRODUCTS DIVISION

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